This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

B 811,569

THE UNIVERSITY OF MICHIGAN · LIBRARIES ·

Bulletin 77

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, DIRECTOR

THE ELECTRIC FURNACE IN METALLURGICAL WORK

BY

DORSEY A. LYON, ROBERT M. KEENEY
AND
JOSEPH F. CULLEN

WASHINGTON
GOVERNMENT PRINTING OFFICE
1914

The Bureau of Mines, in carrying out one of the provisions of its organic act—to disseminate information concerning investigations made— prints a limited free edition of each of its publications.

When this edition has been exhausted, copies may be obtained at cost price only through the Superintendent of Documents, Government Printing Office, Washington, D. C., who is the authorized agent of the Federal Government for the sale of all publications.

The Superintendent of Documents *is not an official of the Bureau of Mines.* His is an entirely separate office and he should be addressed:

SUPERINTENDENT OF DOCUMENTS,
Government Printing Office,
Washington, D. C.

The general law under which publications are distributed prohibits the giving of more than one copy of a publication to one person. Additional copies must be purchased from the Superintendent of Documents. The price of this publication is 25 cents

First edition. October, 1914.

CONTENTS.

PART I. Design, construction, and operation of electric furnaces, by D. A. LYON and J. F. CULLEN.

Page.

Introduction........ 1

Development of use of electricity in metallurgical work........ 2

Field of the electric furnace in metallurgy........ 2

Comparison of the electric furnace and the combustion furnace........ 3

  Method of producing heat in the two furnaces........ 3

  Comparison of heating efficiency........ 4

  Limitations to electric heating........ 5

  Summary........ 6

Classification of electric furnaces........ 7

  Resistor furnaces........ 7

    Solid resistor furnaces........ 8

      Furnaces developing heat in the charge itself........ 8

      Furnaces developing heat in a core........ 8

      Furnaces with a wall between core and charge........ 9

      Furnaces without wall between core and charge........ 9

    Furnaces in which the resistor is a liquid........ 10

      Electrolytic furnaces........ 10

      Nonelectrolytic furnaces........ 10

  Arc furnaces........ 11

Factors governing design and construction of electric furnaces........ 12

  Relation between electric energy and heat........ 12

    Methods of heating with electricity........ 13

      Direct heating by resistance........ 13

      Induction heating........ 13

      Construction of the induction furnace........ 15

      Indirect-resistance heating........ 15

      Arc heating........ 16

  Factors affecting efficiency........ 17

    Induction currents........ 17

      Self-induction........ 17

      Eddy currents........ 18

    Hysteresis........ 18

    Lag........ 19

    Electromechanical forces in the induction furnace........ 19

      Pinch effect........ 19

      Centrifugal effect........ 21

    Power factor........ 21

      Measurement of power factor........ 21

      Use of Ohm's law........ 22

    Power circuits........ 23

    Regulation of the electric current........ 24

    Electrolysis........ 25

      Electrolysis of water........ 25

      Electrolysis of copper sulphate........ 25

      Prerequisites of an electrolyte........ 26

      Essential details of electrolysis........ 26

Factors governing design and construction of electric furnaces—Contd. Page.

- Mechanical construction of furnaces........ 27
  - Factors affecting output........ 27
  - Calculation of energy required........ 28
  - Current and voltage necessary........ 29
  - Proper size of interior of furnace........ 29
  - Proper shape of crucible........ 30
  - Types of furnace linings........ 30
    - Acid refractories........ 30
      - Silica........ 30
      - Dinas brick........ 30
      - Ganister........ 31
      - Fire clay........ 31
    - Basic materials........ 32
      - Lime........ 32
      - Magnesia........ 32
      - Electrically calcined magnesite........ 32
      - Bauxite........ 32
    - Neutral linings........ 33
      - Carbon........ 33
      - Chromite........ 34
      - Alundum........ 34
      - Carborundum........ 35
      - Crystolon........ 35
  - Suitable refractories........ 36
  - Melting points of refractory materials........ 37
  - Proper thickness of furnace walls........ 38
  - Heat conductivities of furnace-wall materials........ 38
  - Proper volume of crucible........ 39
  - Insulation desirable........ 39

Electrodes........ 41

- Manufacture of electrodes........ 42
- Carbon compared with graphite electrodes........ 42
- Energy loss in electrodes........ 42
- Efficiency of electrodes........ 43
- Conductivity of electrodes........ 43
- Essentials in use and design of furnace electrodes........ 43
  - Wattage as a measure of flow of heat........ 44
  - Formulas........ 45
  - Determination of proper size of electrodes........ 45
  - Proper construction of electrode holders........ 47
    - Heat sockets and clamps........ 47
    - Top holders........ 47
    - Side holders........ 48
    - Essential details of holders........ 48
    - Specially shaped electrodes........ 49
    - Types of top holders........ 50
    - Movable side holders........ 55
    - Metallic conductors in electrode heads........ 57
    - Electrode dimensions and electrode bundles........ 60
  - Joining of electrodes........ 65
    - Electrical loss at joints........ 66

Page.
Cost of electric power........ 67
  Hydroelectric power........ 67
  Power produced by gas engines and steam turbines........ 68
Operating conditions of electric furnaces........ 70
Conclusion........ 71

PART II. The smelting of metals in the electric furnace, by D. A. LYON and R. M KEENEY.

Introduction........ 72
Aluminum........ 72
  Introduction........ 72
  Prerequisites for the production of aluminum by present methods........ 73
  Processes for purifying bauxite........ 73
  Hall process for producing aluminum........ 74
  Héroult process for the manufacture of aluminum........ 75
  Serpek process........ 76
  Present status of aluminum manufacture in the United States........ 77
  Factors governing growth of aluminum industry........ 78
  New sources of alumina........ 78
  Processes for producing aluminum from ores other than oxides........ 79
    Tone's method........ 79
    Bett's process........ 80
Iron........ 81
  Present status of electric furnace in smelting iron ores........ 81
    Use of coke and charcoal........ 81
    Possible use of crude oil as a reducing agent........ 84
    Use of electric iron reduction furnace at present........ 84
  Engineers' report of the experimental work at Trollhättan........ 85
    Quality of pig iron produced in electric furnace........ 85
      Value of gas produced........ 86
Copper........ 87
  Present status of the electric smelting of copper ores........ 87
  Experimental work of Vattier, Schilowski, Wolkoff, and others........ 87
  Summary........ 88
Lead ores and complex sulphide ores........ 89
Gold and silver ores........ 90
Zinc........ 91
  Present methods of zinc smelting........ 91
  Zinc smelting in the electric furnace........ 92
  Electric zinc smelting at Trollhattan and Sarpsborg........ 93
    Equipment at the two plants........ 93
    Smelting process........ 93
    Results of operation of furnaces........ 94
      Comments by Harbord and Moulden........ 95
  Experiments at McGill University........ 96
  Experiments of Johnson........ 97
  Electric smelting of zinc sulphide ores with iron as a desulphurizing agent.. 97
  Present status of electric zinc smelting........ 98
    Difficulty of condensing zinc vapor into metal........ 99
    The electrode problem........ 99
    Retort and electrode consumption........ 99
    The fundamental difficulty........ 100
Tin........ 101

PART III. The manufacture of ferro-alloys in the electric furnace by R. M. KEENEY.

Page.
Introduction........ 102
Early development of the manufacture of ferro-alloys........ 103
  Development previous to the use of the electric furnace........ 103
  Introduction of the electric furnace........ 104
Present status of the manufacture of ferro-alloys in the electric furnace........ 105
Types of electric furnaces used in ferro-alloy manufacture........ 106
  Ferrosilicon furnace of the Siemens type........ 106
  Keller furnace........ 108
  Chaplet furnace........ 109
  Girod resistance crucible furnace........ 109
  Girod arc furnace........ 110
  Meraker furnace........ 111
  Series furnace........ 112
  Helfenstein furnace........ 113
  General construction of electric ferro-alloy furnaces........ 113
    Fundamental parts........ 113
    Construction and life of linings........ 115
    Electrode holders........ 115
      Types........ 115
    Waste of heat in open-top furnaces........ 116
    Character of electric current........ 117
Some European electric-furnace ferro-alloy plants........ 118
  Keller, Leleux & Co., Livet, Isère, France........ 118
    Power supply........ 118
    General plan of the works and furnaces........ 119
    Products........ 119
  Société Électro-Métallurgique Procédés Paul Girod, Ugine, Savoie, France. 120
    Power supply........ 120
    General plan of the works........ 121
    Production........ 122
  Meraker Electric Smelting Co........ 122
    Power supply........ 123
    General plan of works and furnaces........ 123
    Products........ 124
Ferro-aluminum........ 125
Ferroboron........ 125
Ferrochrome........ 127
  History........ 127
  Work of experimenters........ 127
    Neumann........ 127
    Moissan........ 128
  Experimental smelting of chromite in the electric furnace........ 128
    Construction of furnace used........ 128
    Materials used in charge........ 128
    Results obtained........ 129
  Theory of chromite smelting........ 131
    Reduction with carbon........ 131
    Reduction with silicon and other reducing agents........ 133
    Refining of ferrochrome........ 134
  Manufacture of ferrochrome........ 135
    Ores and raw materials used........ 135
    Types of furnaces used........ 136
    Process of manufacture........ 136

Ferrochrome—Continued.

Page.

Manufacture of—Continued.

Power and electrode consumption........ 138
Cost of manufacture of ferrochrome........ 139
Selling prices of ferrochrome........ 140
Uses of ferrochrome........ 140
Ferromanganese........ 141
History........ 141
Experiments in the production of ferromanganese........ 142
Theory of production........ 142
Process of manufacture........ 143
Uses of ferromanganese........ 144
Ferromanganese-silicon........ 145
Electric smelting of molybdenite and the production of ferromolybdenum........ 146
History........ 146
Investigators........ 146
Guichard........ 147
Lehner........ 147
Neumann........ 147
Experiments on reduction of molybdenite........ 148
Theory........ 149
Process of manufacture........ 150
Uses........ 150
Ferronickel........ 151
Experiments on the production of natural alloys of nickel directly from ore in the electric furnace........ 151
Experiments at Sault Ste. Marie........ 151
Experiments at plant in North Carolina........ 153
Experiments of Stephan........ 153
Ferrophosphorus........ 154
Ferrosilicon........ 154
History........ 154
Theory........ 155
Silicides of iron........ 155
Properties of ferrosilicon........ 158
Disintegration and evolution of gas from ferrosilicon........ 160
Reduction with carbon........ 161
Production from iron ore of ferrosilicon containing 30 per cent silicon........ 162
Production of ferrosilicon containing 30 per cent silicon from iron turnings........ 163
Fifty per cent ferrosilicon........ 163
Manufacture of ferrosilicon in the blast furnace........ 163
Manufacture of ferrosilicon in the electric furnace........ 164
Raw materials used........ 164
Character of ferrosilicon plants........ 166
Practice........ 167
Method of charging........ 167
Tapping........ 169
Changing electrodes........ 169
Slag formation........ 170
Results of early operations........ 170
Power consumption........ 171
Workmen required........ 171
Products........ 172
Packing and transportation of ferrosilicon........ 172
Cost of manufacture........ 173
Uses........ 174

Page.
Alloys of iron and silicon with other elements 175
Ferrotitanium 175
Electric smelting of tungsten ores and the production of ferrotungsten 177
  History 177
  Experiments of Stassano 178
  Experiments with Colorado ferberite 178
    Conclusions 180
  Theory of tungsten alloys 180
    Reactions 181
  Process of manufacture 182
  Uses 184
Electric smelting of vanadium ores and the production of ferrovanadium 184
Glossary 186
Selected bibliography 190
Publications on metallurgy and mineral technology 208

ILLUSTRATIONS.

Page.
FIGURE 1. Acheson graphite furnace 8
2. Cross section of electrically heated tube furnace 9
3. Acheson carborundum furnace 9
4. Heroult 2.5 ton, single-phase steel furnace 10
5. Stassano furnace 11
6. Cross section of Siemens vertical-arc heating furnace 12
7. Curve representing a complete wave or cycle of alternating current 13
8. A magnetic field, in which a conductor has been placed 14
9. Cross section of Girod furnace 16
10. Cross section of Helberger furnace 16
11. Cross section of Moissan furnace (after Stansfield) 17
12. Cross section of the bath of an induction furnace, showing effect on surface of bath of the resultant of the different forces acting 19
13. Different types of electric furnace connections 24
14. Trollhåttan electrode before and after use 47
15. Specially shaped electrodes for electric furnaces 49
16. Holder formerly used with carbide furnaces 50
17. Electrode holder with cooling device 51
18. Electrode holder with another type of cooling device 52
19. Detailed views of electrode holder satisfactorily used in carbide furnaces 53
20. Another type of electrode holder satisfactorily used in carbide furnaces 54
21. Water-cooled electrode holder 55
22. Holder for round electrode 56
23. Electrode holder cooled with water under pressure 57
24. Electrode holder used in Germany 58
25. Electrode holder with movable contact 59
26. Holder for a block electrode 60
27. Modification of holder for block electrode 61

Page.
FIGURE 28. Electrode holder used by the Aktisbolaget Elektrometall Ludwika. 62
29. Electrode holder used by Nathusius........................... 63
30. Electrode with iron connection in top......................... 63
31. Screw-bolt electrode connection............................... 63
32. Combination of four screw-bolt electrodes...................... 64
33. Electrode connection used by Lessing.......................... 64
34. Electrode connection used by Keller........................... 64
35. Electrode holder used in Stassano furnace...................... 65
36. Three types of electrode joints................................ 66
37. Aluminum furnace.. 75
38. Plan and elevation of Siemens type of ferrosilicon furnace........ 106
39. Electrodes and holders used in Siemens type of ferrosilicon furnace. 107
40. Keller ferro-alloy furnace..................................... 108
41. Plan and elevation of Chaplet ferro-alloy furnace................ 109
42. Plan and elevation of Girod resistance furnace.................. 110
43. Plan and elevation of Girod electrode ferro-alloy furnace......... 110
44. Plan and elevation of ferrochrome furnace at Kopperaaen, Norway. 111
45. Norwegian and Italian electrodes and holders.................... 111
46. Plan and elevation of single-phase series ferro-alloy furnace....... 112
47. Elevations of three-phase series ferro-alloy furnace............... 113
48. Elevation of Helfenstein furnace................................ 114
49. System of electrical connections for several small furnaces........ 114
50. Delta connections of three single-phase furnaces.................. 117
51. Electrical connections of a three-phase furnace.................. 118
52. Plan of Girod ferro-alloy plant................................. 121
53. Cooling curves of the iron silicon system........................ 157
54. Specific gravity curves of ferrosilicon samples containing varying percentages of ferrosilicon.................................... 159
55. Plan of ferrosilicon plant designed by Conrad and Pick.......... 167
56. Elevation of Conrad and Pick's ferrosilicon plant................. 168

IV

Fact

THE ELECTRIC FURNACE IN METALLURGICAL WORK.

By Dorsey A. Lyon, Robert M. Keeney, and Joseph F. Cullen.

PART I. DESIGN, CONSTRUCTION, AND OPERATION OF ELECTRIC FURNACES.

By Dorsey A. Lyon and Joseph F. Cullen.

INTRODUCTION.

In connection with its investigation looking to the prevention of waste and the increase of safety and efficiency in the mineral industries the Bureau of Mines has undertaken a study of the possible uses of the electric furnace in metallurgy. This bulletin presents a compilation of such data as seem to be useful for the information of persons who may be interested in the matter. In the application of electricity to metallurgy three kinds of processes are involved, namely, mechanical, thermal, and electrolytic.

Under the mechanical application of electricity come those processes of dressing and concentrating ores that are known as either electrostatic or electromagnetic processes.

In electrothermic processes the current is used as a source of heat. The fundamental differences between the various types of electric furnace that are at present in commercial use relate to the manner in which the electric current is applied, as may be noted by reference to that part of this report in which the subject is discussed.

In electrolytic processes the electric current is used for depositing metals from solutions. The process may be conducted in one of the following ways: (1) The material to be treated may be put into solution and then electrolyzed, the material thus treated forming the electrolyte; (2) the material to be treated may form the anode or be placed in contact with the anode; or (3) the material to be treated may form the cathode or be placed in contact with the cathode.

This report treats of electrothermic processes, with the possible exception of those for the reduction of aluminum from its ores. Moreover, of the processes used in the so-called electrochemical industries only those for the reduction of an ore to metal, or to a compound of the metal that is of value in itself, or is an aid in metallurgical work, are here discussed.

DEVELOPMENT OF USE OF ELECTRICITY IN METALLURGICAL WORK.

The use of electricity as a source of heat in metallurgical work is comparatively recent. Although many chemists and metallurgists had previously conducted small experiments, Siemens, in 1882, was probably the first to make use of it in metallurgical work for commercial purposes.[a] Then came the furnace of E. H. and A. H. Cowles,[b] who in 1885 invented a furnace for the production of aluminum alloys and for a variety of other purposes. A year later Paul Héroult[c] and C. M. Hall[d] patented processes for the production of aluminum. In 1893 Wilson,[e] aided by data gathered by Moissan in his classical experiments, developed the calcium-carbide furnace, which was followed in 1896 by Acheson's carborundum furnace.[f] Two years later Captain Stassano of Italy patented an electric furnace[g] for smelting iron ores, and the following year demonstrated the working of his process. In 1900 the production of ferro-alloys in the electric furnace was begun, and at the present time practically all ferro-alloys are made in electrically heated furnaces.

As a result of the work of Stassano and of the successful making of ferro-alloys in the electric furnace, steel was next made in France by Héroult and in Sweden by Kjellin under patents taken out in 1900. In 1906 experiments on the reduction of iron ores in the electric furnace were conducted by the Canadian Government and by Grönwall, Lindblad, and Stalhane in Sweden. The production of pig iron in the electric furnace in Sweden at the present time is a direct result of the work of the three men last mentioned.

In the development of the electric furnace its uses have been extended, and to-day it is used not only in metallurgy but in many branches of applied chemistry as well.

FIELD OF THE ELECTRIC FURNACE IN METALLURGY.

The electric furnace is not necessarily a competitor of the combustion furnace, for it has won its position in the industrial world chiefly through the fact that it permits the use of a higher temperature than can be attained with the combustion furnace. This is why, for example, high-grade ferrosilicon and many of the ferro-alloys are not produced in the combustion furnace. Again, the electric furnace is particularly suited to the production of those elements that may themselves constitute the walls of the furnace, so that it is possible to effect a great saving in crucibles and retorts, the cost of which was a large item in older methods. As the best illustration of such products, phosphorus and carbon bisulphide may be cited.

---

[a] Siemens, William, and Huntingdon, —, Report of 52d meeting: British Assoc. Adv. Science, August, 1882, pp. 496–498.

[b] U. S. patent 319795 (1884).

[c] French patents 175711, April 23, 1886; and 170003, April 15, 1887.

[d] U. S. patents 400766 and 400664, April 2, 1889 (applied for July 9, 1886).

[e] Wilson, T. L., Industries and Iron, vol. 20, 1896, p. 322.

[f] Fitzgerald, F. A. J., The carborundum furnace: Electrochem. Ind., vol. 4, 1906, p. 53.

[g] Electrochem. and Met., vol. 1, 1901, p. 230; Electrochem. Ind., vol. 1, 1902–3, pp. 247–363.

In short, the advent of the electric furnace into metallurgy has made possible developments that were not possible through the use of the combustion furnace. For example, such substances as magnesia, lime, and molybdenum were formerly considered infusible, but at the high temperature attained in the electric furnace these substances are not only melted but may be volatilized. New processes based on this development have been perfected for the purification and separation of substances, and metals and their combinations may be separated by fractional distillation in the same general way as substances having comparatively low boiling and volatilizing points.

It is perhaps true that some metallurgists have unduly emphasized the importance of the electric furnace in metallurgical work, and for that reason it may be well briefly to consider a few of the fundamental facts regarding the possibilities of the use of high temperatures.

In the first place, it is thought that any known oxide can be reduced by carbon within the range of temperature possible in the electric furnace. At any rate, it is easy in such a furnace to reduce such stable oxides as those of calcium, silicon, and magnesium, and to produce carbides of these elements as well as those of boron, aluminum, molybdenum, tungsten, and titanium. These carbides are extremely stable, resisting not only attacks of water, but also most of the active chemical agents.

The writers have purposely emphasized the fact that the electric furnace is not a competitor of the combustion furnace, but has its own particular field of usefulness. However, quite possibly it may in time become a competitor of the combustion furnace for certain work, and, in fact, it already is to some extent.

COMPARISON OF THE ELECTRIC FURNACE AND THE COMBUSTION FURNACE.

METHOD OF PRODUCING HEAT IN THE TWO FURNACES.

As is well known, in the combustion furnace heat is produced by the oxidation of some combustible substance, the product of combustion being a gas. The efficiency attained, or the ratio between the amount of heat usefully employed in the furnace and the heat value of the fuel or electric energy supplied, is generally rather low, a fair average being probably about 25 per cent. On the other hand, the source of heat in an electric furnace is electrical energy, and it is perhaps fair to assume that the average efficiency of such a furnace is 60 per cent, whereas in the combustion furnace it is perhaps never more than 66 per cent, as shown in the following tables:

Average thermal efficiency of various types of combustion furnaces.

Type of furnace.	Product.	Thermal efficiency.[a]
		Per cent.
Blast	Cast iron	52 to 66
Acid process	Steel	11.9
Basic process	....do	10.0
Reverberatory	Pig iron	8.5
Do	Wrought iron	5
Siemens crucible	Steel	4
Greenwood crucible	....do	2
Retort	Zinc	2 to 3

[a] Average efficiency for steam, 50 to 60 per cent.

Average thermal efficiency of three types of electric furnace.

Type of furnace.	Product.	Horse-power.	Temperature.	Thermal efficiency.
			° *C.*	*Per cent.*
Acheson	Graphite	1,000	3,300	75
Jacobs	Fused Al_2O_3	200	....	74
Acheson	Carborundum	1,000	3,000	76.5

COMPARISON OF HEATING EFFICIENCY.

Some idea as to the heating value of electrical energy as compared to that of coal may be obtained from the following discussion of "Electric heat versus heat from fuel."[a]

One kilowatt-hour[b] is equivalent to 860 kilogram-calories, which is approximately the full heat obtained from 100 grams of good coal when completely burned to carbon dioxide. If the cost of a ton of coal of 2,000 pounds (907 kg.) is a dollars, and if the efficiency of heat production by burning coal is x per cent, then the coal required for producing 860 kilogram-calories costs a divided by 90.7 x dollars. On the other hand, if the cost of 1 kilowatt-hour is b cents and if the efficiency of producing heat from electrical energy is y per cent, then the kilowatt-hours required for producing 860 kilogram-calories cost b divided by y dollars. Hence electrical heat will be cheaper than heat produced by combustion of fuel if $a\ y$ is greater than 90.7 $b\ x$. To go further, we need the efficiency figures x and y. By assuming definite figures we introduce, of course, an uncertainty into our comparison, but it will probably be considered fair if, for a first approximation, we assume a 25 per cent efficiency for fuel heating and a 75 per cent efficiency for the electric furnace. Then we conclude that electrical heat will be cheaper than heat produced from fuel if a is greater than 30.2 b, or, in other words, if the cost of a ton of coal in dollars is more than 30 times the cost of a kilowatt-hour in cents. For instance, to compete with coal at $6 per ton, the electric kilowatt-hour would have to cost less than 0.2 cent. This is clear evidence that if the electric furnace did not have other important features it would not compete with fuel heat under ordinary conditions.

---

[a] Electrochem. and Met. Ind., vol. 5, 1907, p. 298.

[b] For definition of electrical units, see p. 186.

We have purposely made this comparison on the basis of the ton of coal and of the kilowatt-hour, although it has become customary to use the electric horsepower-year as the unit of electrical energy in such estimates. Then the above condition can be stated in this way: Electric heat will be cheaper than fuel heat if the cost of 1 ton of coal is more than one-half of the cost of the electric horsepower-year. Stated in this form, the comparison looks more favorable for the electric furnace than when stated as in the preceding paragraph. But in reality it is not proper to make the comparison on the basis of a horsepower-year, since we thereby implicitly assume that the electric furnace is working continuously every hour all year round, which is in general a decidedly improper assumption.

It is, of course, clear that the above comparison is exceedingly narrow in that it considers only one single side of the problem, namely, the amount of fuel and electrical energy required to produce the same number of calories. But even in this very respect the above comparison falls short of the truth and does not do justice to the electric furnace. The chief reason is that electrical heating is essentially internal heating, permitting a very high concentration of energy at any point wanted and thus enabling one to produce high temperatures. Fuel heating, on the other hand, is always more or less transmission of heat from the fuel to the charge, and the rate of heat transmission depends on the difference of the two temperatures; this rate decreases rapidly the higher we go up in the temperature. Naturally with fuel heating we can never obtain any higher temperature than that of the burning fuel itself. There is no corresponding limitation in electric heating. This is the fundamental reason why for all very high temperature processes the electric furnace reigns supreme.

LIMITATIONS TO ELECTRIC HEATING.

It is necessary to qualify the statement that there is no limitation to electric heating. Theoretically there is not, but practically there is, for the following reasons: As an electric current passes through a conducting medium heat is produced. The intensity of this heat depends on the amount of current that passes, and as most substances are conductors when hot, the degree of intensity possible is theoretically unlimited. In practice, however, the conducting substance begins to fuse when heated to its melting point, and one is then confronted with the physical difficulty of keeping the conducting medium in place. Or if this be accomplished, the conducting medium ultimately vaporizes, the gaseous materials escape, and heat is thus carried away from the furnace as rapidly as it is supplied. The temperature of the electric arc, which is somewhere between 3,600° and 4,000° C., is perhaps the highest temperature attainable at present.

Theoretically it is possible to obtain by the combustion of carbon in oxygen a higher temperature than can be attained in the electric furnace. In practice, however, the attainment of such temperature is impossible for the following reasons:

1. At high temperatures carbon oxidizes to CO and not to CO_2. The oxidation of 1 pound of carbon to CO_2 generates 8,100 pound-calories, whereas the oxidation of 1 pound of carbon to CO generates only 2,430 pound-calories.

2. The gaseous products formed escape rapidly and carry heat away from the furnace.

3. In commercial work, at present at least, it is not feasible to supply pure oxygen for combustion purposes.

4. Atmospheric oxygen is accompanied by four times its volume of nitrogen, so that when air is used instead of pure oxygen the nitrogen is raised to a high temperature and carries from the furnace the heat it has absorbed.

SUMMARY.

The foregoing paragraphs may be briefly summarized, as in the following sentences:

In the combustion furnace, no matter what form of fuel is used, the temperature can not exceed 2,000° C.

In the combustion furnace the efficiency varies from 2 per cent to 60 per cent, whereas in the electric furnace it averages about 60 per cent.

In the combustion furnace not only is it necessary to take care of the products of combustion, but these products may reduce the efficiency of the process, whereas the electric furnace is free from these difficulties.

In the electric furnace the temperature attainable is the same whether the furnace is operated on a commercial or on a laboratory scale.

In the electric furnace, the heat may be developed at any desired point, and by passing the current through the substance that is to be treated the heat necessary for the operation may be developed within the substance itself.

The temperature of an electric furnace is under absolute control.

Any atmosphere desired—that is, neutral, oxidizing, or reducing—may be obtained within the electric furnace. This feature, together with the fact that the product is generally much purer than that of the combustion furnace, is a great factor in favor of the electric furnace.

In general, one may say that it is necessary to use an electric furnace in all operations requiring a temperature higher than 2,000° C.; for work requiring a temperature of less than 2,000° C., local conditions and the nature of the work to be done will affect the choice of the electric or the combustion furnace. As has been previously pointed out, the cost of power will largely enter into the matter, but even with a high cost of electric power, the superior efficiency of the electric furnace, the possibility of obtaining a purer product, and perhaps greater safety for the workmen—any or all of these factors may lead to a decision in favor of the electric furnace.

CLASSIFICATION OF ELECTRIC FURNACES.

Electric furnaces may be classified in a more or less arbitrary manner, and different authorities have used such classifications as seemed most desirable. Stansfield's classification [a] is substantially as follows:

- I. Arc furnaces:
  - A. Those with independent arc (Moissan furnace).
  - B. Those with direct-heating arc (Siemens vertical-arc furnace).
- II. Resistance furnaces:
  - A. Those with special resistor—
    - 1. Furnaces in which charge constitutes the resistance (carborundum furnace).
    - 2. Furnaces having resistor in walls (electrical tube furnace).
  - B. Those without special resistor—
    - 1. Furnaces in which electrolysis is not employed (charge constitutes the resistance):
      - (*a*) Those in which the charge is not melted, but remains in a solid condition (graphite furnaces).
      - (*b*) Those in which charge is added in solid condition but subsequently becomes liquid (Héroult ore-smelting furnaces).
      - (*c*) Those in which charge is added in liquid condition (Kjellin steel furnaces).
    - 2. Electrolytic furnaces (furnaces for producing aluminum).

Burgess [b] classifies electric furnaces according to the character of the medium constituting the conductor, as follows:

I. Furnaces in which the heat is developed by the passage of current through a solid conducting medium or "resistor."

A. The conducting medium, or core, may consist of the material that is to undergo useful transformation.

B. The heat is developed in a core of conducting material and this heat in turn is communicated to the surrounding material that constitutes the charge, either with or without a wall between the two cores and the charge.

II. Furnaces in which the heat is developed by the passage of current through a solid or liquid conducting medium.

A. Electrolytic.

B. Nonelectrolytic.

III. Furnaces in which the heat is developed by the passage of current through a gaseous conducting medium.

A. Arc furnaces.

(1) In which an arc plays between two or more electrodes in the neighborhood of material to be treated.

(2) In which an arc is maintained between one carbon electrode and the material to be treated, the latter acting as a second electrode.

RESISTOR FURNACES.

A resistor signifies a substance that is used as a medium for developing heat when electric current is passed through it. As stated by Burgess in his classification of electric furnaces, a resistor may be either a solid, a liquid, or a gas. Materials commonly used for this purpose are the metals, carbon, and substances that are not conductors at ordinary temperatures, but become conductors when hot. When such substances are used, it is necessary first to heat them by some auxiliary means. The construction of a resistance furnace is based upon the fact that by resistance an electric current is transformed into heat.[a]

---

[a] Stansfield, A., The electric furnace, its evolution, theory, and practice, 1907, p. 32.

[b] Burgess, C. F., The present status of electric furnace working: Jour. Western Soc. Engrs., vol. 10, 1905, p. 167.

SOLID RESISTOR FURNACES.

FURNACES DEVELOPING HEAT IN THE CHARGE ITSELF.

Furnaces in which the heat is developed by passage of the current through a solid conducting medium are described below.

An illustration of the type of furnace in which the conducting medium, or core, may consist of the material that constitutes the charge is the Acheson graphite furnace, shown in figure 1.[b] In this furnace a core, *c*, of carbon rods is needed to carry the current until the charge becomes heated. The base, *b*, and end walls, *aa*, which support the electrodes, are permanent, but the side walls, *dd*, are not, and can be pulled down after a run. The electrodes comprise a number of graphite rods, *e*, which are set in a block of carbon as shown in the figure; electric contact being made by a terminal plate, which may be water-cooled. In making graphite in a furnace of this kind a charge of anthracite coal, *g*, is placed around the core of carbon rods, *c*, and then covered with a layer of material that is a poor conductor of both heat and electricity. When the current is turned on, it passes through the core of carbon rods and heats the anthracite, which is gradually converted into graphite by the high temperature attained. The electrical resistance of the graphite is very low, and for that reason the current has little tendency to pass through the outer parts of the charge.

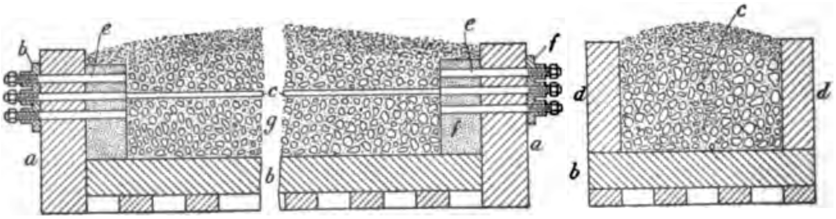


FIGURE 1.—Acheson graphite furnace.

FURNACES DEVELOPING HEAT IN A CORE.

That type of furnace in which the heat is developed in a core of conducting material, this heat being in turn communicated to the surrounding material that constitutes the charge, may or may not have a wall separating the core from the charge.

---

[a] For laws of electrical resistance, see p. 187.

[b] Stansfield, A., The electric furnace, 1907, p. 145.

FURNACES WITH A WALL BETWEEN CORE AND CHARGE.

The electrically heated tube furnace (fig. 2) is an example of the type of furnace having a wall between the core and charge. As is shown in the figure, it is constructed by winding a wire, *r*, which forms the resistor, around a tube, *t*, which is made of porcelain or some other highly refractory substance. The resistor wire may be of either platinum or an alloy, such as nickel and chromium, that has a high fusing temperature. In some furnaces of this type, the resistor wire, instead of being wound around a tube, is embedded in the inner surface of the refractory envelope, *e*. In the operation of the tube furnace the charge is placed in the tube, the leads *a* and *b* are connected to an electric circuit and, by means of a controlling rheostat, enough current is supplied to the resistor wire to overload it, so to speak, and the resistance that the current meets transforms the electric energy into heat. By varying the intensity of the current it is possible to obtain any desired temperature below the melting point of the wire, which for platinum is 1775° C. or 3227° F.

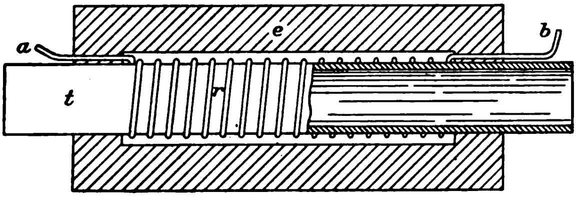


FIGURE 2.—Cross section of electrically heated tube furnace.

FURNACES WITHOUT WALL BETWEEN CORE AND CHARGE.

The Acheson carborundum furnace,[a] shown in figure 3, is an example of the type of furnace in which there is direct contact between the core and the charge.

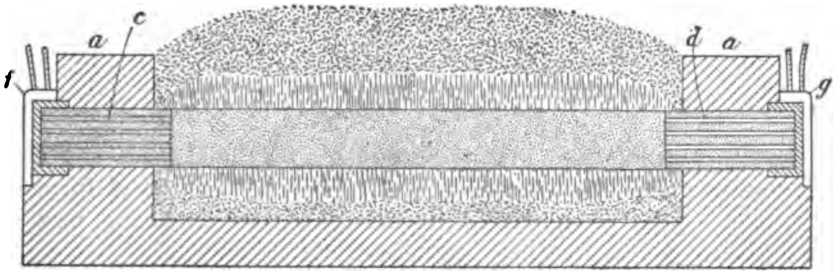


FIGURE 3.—Acheson carborundum furnace.

The end walls *aa* are permanent, and support the heavy bronze electrode holders *f* and *g*. Inserted into these holders are large bundles of carbon rods, *c* and *d*, and between the rods is a core of broken carbon which remains until the end of the operation. Around this core is placed a mixture consisting approximately of 34.2 per cent coke, 54 per cent sand, 9.9 per cent sawdust, and 1 per cent salt.

---

[a] Fitzgerald, F. A. J., The carborundum furnace, Electrochem. Ind., vol. 4, 1906, p. 53.

The broken carbon core acts as the resistor. When a current is passed through this core it becomes heated and in turn heats the surrounding charge, which then becomes a conductor and acts as a resistor itself.

FURNACES IN WHICH THE RESISTOR IS A LIQUID.

Furnaces in which heat is developed by the passage of a current through a liquid conducting medium are of two types, electrolytic and nonelectrolytic, to use terms already defined.

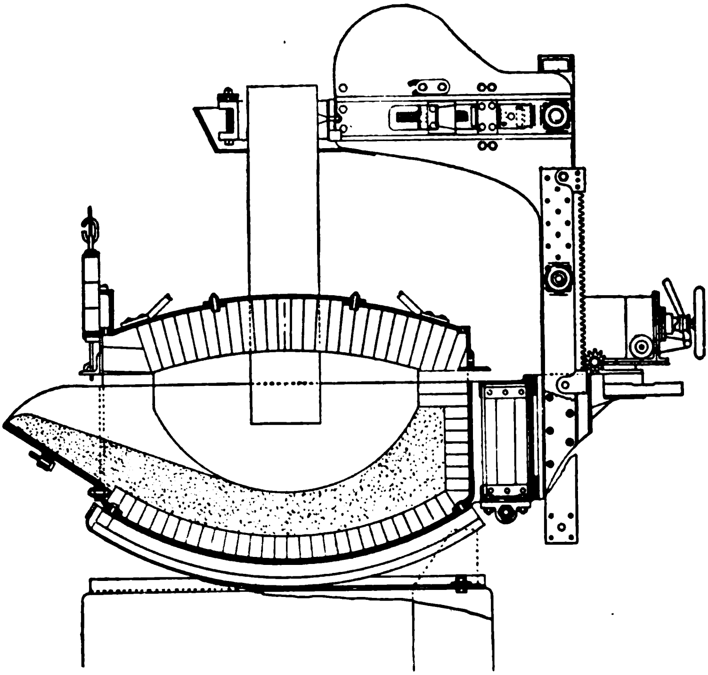


FIGURE 4.—Héroult 2.5-ton, single-phase steel furnace.

ELECTROLYTIC FURNACES.

The furnaces in which aluminum is made by the Héroult and Hall processes are the best examples of the electrolytic type of furnace. Inasmuch as their construction is described in the second part of this bulletin, a description is not necessary here.

NONELECTROLYTIC FURNACES.

The Héroult steel furnace (fig. 4) is illustrative of the nonelectrolytic type of furnace. In this furnace the molten steel is covered with a layer of slag. The heat in the furnace is generated by the passage of the electric (alternating) current between the electrodes through the liquid layers of slag and metal.

ARC FURNACES.

Arc furnaces may be classified, according to the method used in forming the arc, in two general types: (1) Furnaces in which the arc plays between two or more electrodes in the neighborhood of the material to be treated, and (2) furnaces in which the arc is maintained between one carbon electrode and the charge, the latter acting as a second electrode.

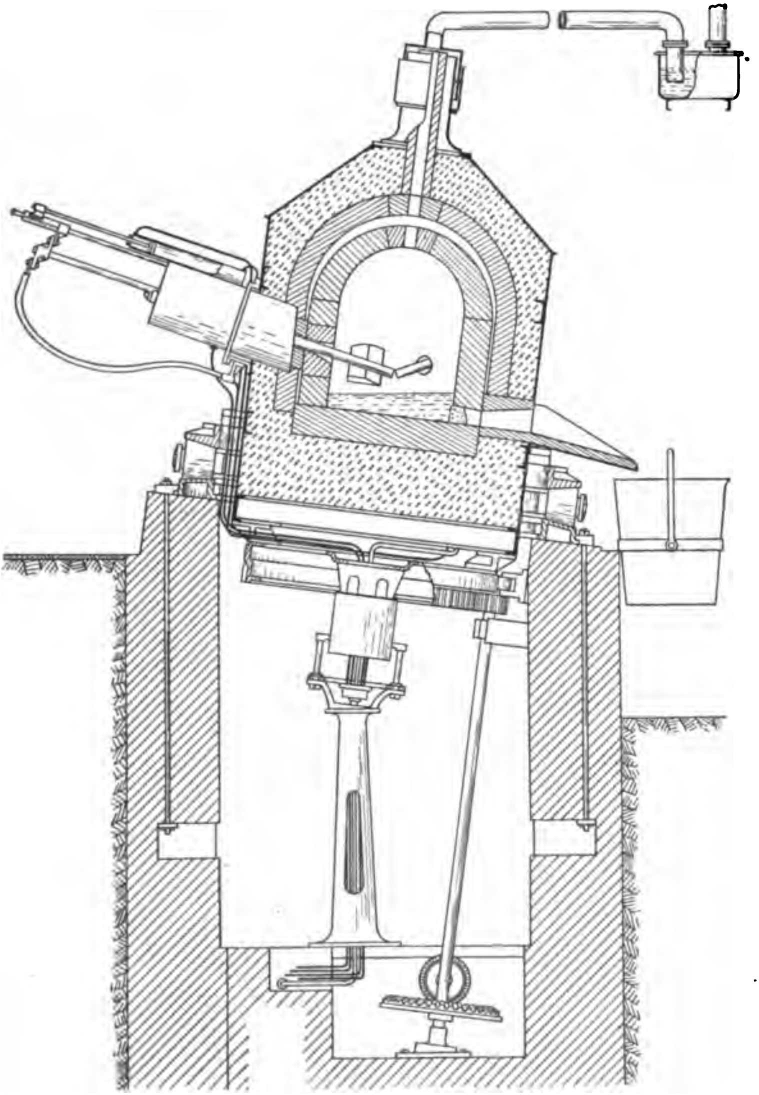


FIGURE 5.—Stassano furnace.

The Stassano furnace (fig. 5) is a good illustration of the first type. An arc is maintained between the ends of two electrodes, and in this way the metal and slag are heated by the heat radiated from the arc.

The Siemens vertical-arc heating furnace, as shown in figure 6, is a furnace of the second type. In this furnace the charge *d*, which is in contact with the lower electrode *c*, is heated by maintaining an arc between the end of the upper electrode *b* and the charge *d*.

FACTORS GOVERNING DESIGN AND CONSTRUCTION OF ELECTRIC FURNACES.

Naturally, in the design and construction of an electric furnace, the aim is to obtain in the operation of the furnace the highest efficiency compatible with the operating conditions. Some of the factors that govern the efficiency of an electric furnace are briefly considered below.

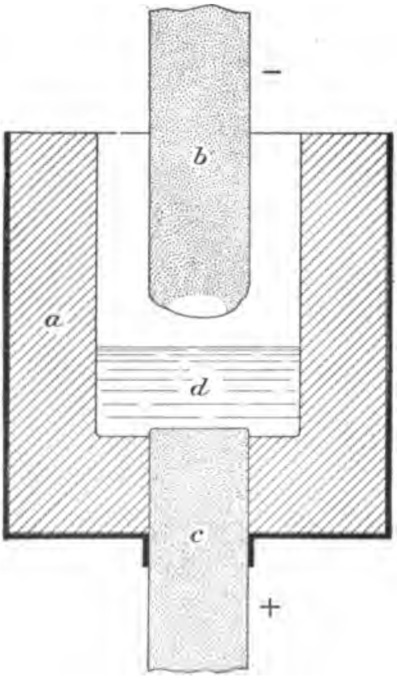


FIGURE 6.—Cross section of Siemens vertical-arc heating furnace.

RELATION BETWEEN ELECTRIC ENERGY AND HEAT.

The measure of the electric power supplied to the electric furnace is the watt. If 1,000 watts be used for one hour, one kilowatt-hour has been used. The expenditure of this much energy is equivalent to 860 kilogram-calories, which represents the full amount of heat to be expected from the complete combustion (to carbon dioxide) of 100 grams of good coal. By calculation it is possible to determine the amount of heat or the temperature necessary to bring about the results desired in any metallurgical process. To attain and maintain this temperature a certain rate of heating is necessary, this rate depending on the rate at which the heat is conducted away through the furnace walls, the dimensions of the furnace, and the cooling effect of the charge that is added from time to time. When, as in the electric furnace, this heat is to be supplied by electrical energy, the first consideration is so to construct the furnace as to obtain the largest practicable percentage of heat value from the electrical energy supplied. In order to do this, the designer must have, of course, a clear understanding of the fundamental laws of electricity[a] and the heating effects of the electric current. The different methods of heating may be briefly stated as follows: Direct heating by resistance; induction heating; indirect resistance heating; and arc heating. The methods are briefly described below.

METHODS OF HEATING WITH ELECTRICITY.

DIRECT HEATING BY RESISTANCE.

An illustration of direct heating by resistance is the heating of a metal bar or wire by passing an electric current through it. The metal will become hot because of its inherent resistance. Increasing the current increases the resistance and consequently the temperature. As can be readily understood, the disadvantage of direct heating by resistance is that not only is the metal or substance heated, but likewise all the conductors that carry the current to it. For this reason copper, which has a much lower specific resistance than iron, is used for a conductor. If an electric current be passed through a copper and an iron wire, each of equal cross section, greater heat is developed in the iron wire, in the proportion of 0.1 to 0.018; hence if the wires are of equal lengths the total amount of heat developed in the iron wire will be much greater than that developed in the copper wire.

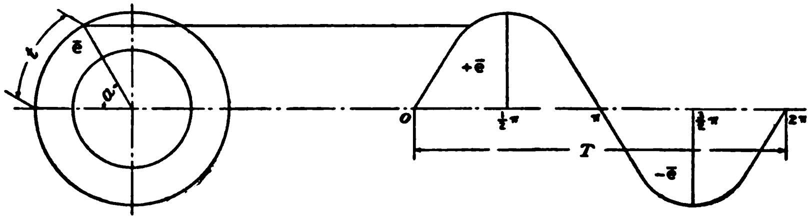


FIGURE 7.—Curve representing a complete wave or cycle of alternating current.

INDUCTION HEATING.

In order to define precisely what is meant by induction heating, it is necessary first to outline the principles upon which such heating is based. As is well known, in a direct electric current the flow is always in the same direction, whereas in an alternating current the direction of flow is constantly being reversed. The time required for a change of direction is called a period. In figure 7, which shows a complete wave or cycle, T represents the time necessary for the current to swing through a complete wave; that is, from 0 (zero) to the positive maximum, back to zero, to the negative maximum, and back to zero. If an alternating current be passed through a coil of wire and if a conductor be passed through the magnetic field of the coil in such a way as to cut the lines of force of the field a current is induced in the conductor. A magnetic field is shown in figure 8 in which *n* and *s* are the poles of a magnet and *c* is a wire conductor (shown in cross section) that is made to cut the lines of force passing between the poles.

---

[a] For the convenience of those not familiar with the same, some of the fundamental laws and terms of electrical engineering are given in the Glossary (pp. 186–189).

In what is known as a transformer the conductor is kept stationary, and the field is made to change or to move across the conductor. If a coil of wire be wound around a core of soft iron and a current passed through the wire, a magnetic field is produced as with a permanent magnet. If the current be suddenly made and broken or if an alternating current be used, the magnetic flux will increase and decrease in first one direction and then the other. Now by winding a second coil of wire on the iron core a conductor is obtained. Every time the magnetic flux (lines of force of the field) increases or decreases in strength as it changes its direction a current will be set up or induced in the second coil or secondary winding and in a direction that tends to oppose the flow of current through the first coil or primary winding.

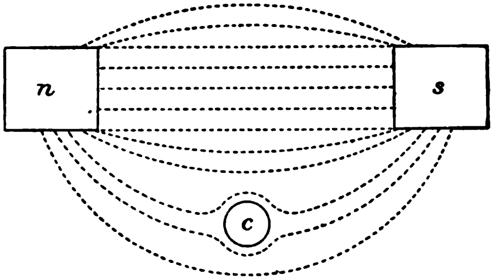


FIGURE 8.—A magnetic field, in which a conductor has been placed.

The current induced in the secondary winding will be inversely proportional to the number of turns on the winding and consequently (by Ohm's law, $\frac{E}{I} = R$) the voltage will be in direct proportion. The foregoing relation does not hold exactly true because the resistance and other properties of the transformer become factors in the application of this law.

With a given voltage the larger the current to be carried the lower must be the resistance of the conductor. The resistance can be lowered by using a conductor of larger size or one made of a material that is a better conductor of electricity. In electrical work copper is generally used for conductors.

From these statements it is evident that heat is generated when an electric current is induced in a conductor, and if the conductor has a high specific resistance, such as that of the bath of steel in an induction furnace, the heat developed is in proportion to the square of the resistance and to the strength of the current induced. This method of heating may be termed heating by induction, and it is most used in electric-furnace practice in steel furnaces, such as those of Kjellin, Colby, and Röchling-Rodenhauser, which are known as induction furnaces.

CONSTRUCTION OF THE INDUCTION FURNACE.

On analyzing the induction furnace its method of construction is found to be based on three essential features, as follows: (1) A primary winding composed of a great many turns of wire or other conductors, (2) a core or circuit for the magnetic flux, and (3) a circular trough containing molten steel, which corresponds electrically to a secondary winding of one turn.

As the secondary winding is of only one turn, an enormous current can be induced in it, and as the steel is not an exceptionally good conductor it becomes heated to a high temperature. For example, in such a furnace as the Kjellin steel furnace the primary winding represents the conductor, through which is passed a current of 90 amperes at 3,000 volts. Around this winding is a circular trough which contains the metal. As the current passes through the primary winding, a magnetic flux, or flow of current, is induced in the metal in the trough, and the current is transformed from 90 amperes at 3,000 volts to 30,000 amperes at 7 volts. By reason of the high amperage of the induced current and the resistance with which it meets in the metal in the trough, sufficient heat to melt the metal is generated.

Although this type of furnace possesses certain advantages, it also possesses several disadvantages, chief among these being that it is inefficient in much the same sense as a poorly constructed transformer is, owing to the fact that it is built on the principle of a transformer. Moreover, when used for heating a metal such as steel, there is also induced in the bath of the induction furnace electromechanical forces, which are discussed in another chapter, that have a tendency to interfere with the working of the furnace.

INDIRECT-RESISTANCE HEATING.

In the indirect-resistance method of heating the heat is not produced by using a metal as a resistor, but by passing the electric current through some substance that has a very low electric conductivity. An example of such a furnace is the Acheson carborundum furnace (fig. 3). In this furnace the charge to be heated is placed around the carbon core. An electric current is passed through the core, which thus becomes hot and in turn heats the charge.

When materials such as crucible steel are heated in crucibles, an indirect method of heating is employed. The crucible furnaces are fired with either coal or gas and have low efficiency (see table, p. 4), owing to the amount of heat that is carried away with the flue gases. The Girod crucible furnace[a] (fig. 9) was devised to do the same kind of work as the ordinary crucible steel furnace. In the

---

[a] Von Baur, C. H., Electric furnaces in the iron and steel industry, 1913, p. 33.

Girod furnace shown in the figure the current is conducted through the bottom, which is made of materials having high electrical resistance, such as carbon and silica. In furnaces of this kind temperatures of 1,400° to 1,700° C. have been reached. In another Girod crucible resistance furnace a resistor of ferrosilicon is used, to which the current is led by four carbon blocks around the crucible.

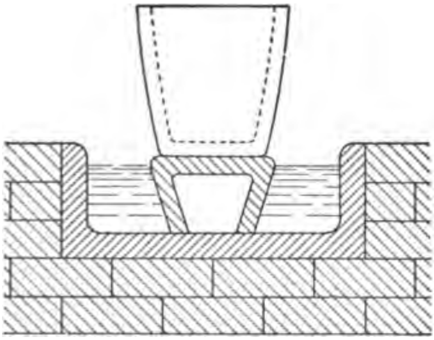


FIGURE 9.—Cross section of Girod furnace.

Still another type of indirect-heating furnace is the Helberger furnace (fig. 10). This furnace consists of a crucible which is placed in circuit by means of carbon contacts, so that the current passes vertically through the crucible walls. Helberger uses the ordinary carbon or graphite crucibles.

ARC HEATING.

Arc heating was employed by Moissan in his famous researches. In figure 11 is shown the Moissan type of furnace, which is described by Stansfield[a] as follows:

It consists of two blocks of limestone and two carbon rods, to which electrical connections are made. A cavity is hollowed out in these blocks, and the material to be heated is placed in a crucible of carbon or magnesia. As even lime melts and volatilizes at the temperature of this furnace, a lining of alternate layers of carbon and magnesia was arranged as shown in the figure, in order to withstand, as far as possible, the heat of the arc.

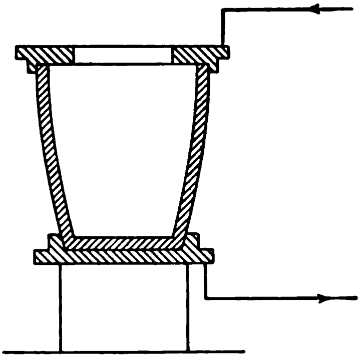


FIGURE 10.—Cross section of Helberger furnace.

In some of these experiments Moissan converted two or three hundred electrical horsepower into heat in a furnace of only a few inches internal dimensions. At the enormously high temperature of his furnace everything melts or turns to vapor. Carbon is the most refractory substance known, and even that turns to graphite and volatilizes; magnesia, another very refractory substance, melts at the highest temperature of the furnace and vaporizes. Lime, quartz, and alumina melt and boil in the furnace. Gold, copper, iron, and in fact all the metals, can also be melted and boiled in such an electrical furnace.

An improved form of the Moissan furnace was described in Engineering[b], March 23, 1906, in which an electric current of 1,000 amperes at from 50 to 150 volts is employed. In the case of direct current this would mean 70 to 200 horsepower, and, while this is not quite as much as Moissan sometimes used, it is more than is often available for scientific experimental work. In such a furnace it is easy to produce a temperature more than double that usually obtainable by the combustion of fuel, and it is, therefore, an invaluable apparatus in the hands of the metallurgist and the chemist.

---

[a] Stansfield, A., The electric furnace, 1907, p. 19.

[b] Anon., One-thousand ampere Moissan electric furnace: Engineering, vol. 81, 1906, p. 381.

Arc heating by radiation finds its practical application in the Stassano furnace, shown in figure 5.

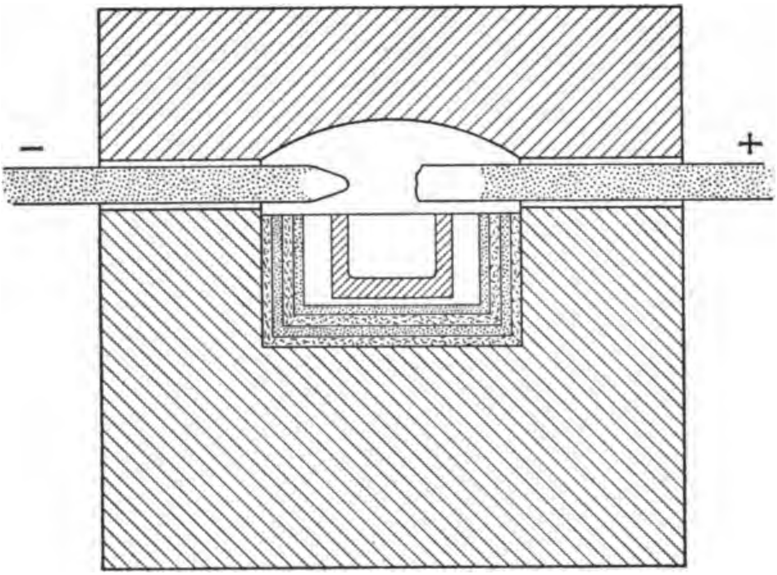


FIGURE 11.—Cross section of Moissan furnace (after Stansfield).

FACTORS AFFECTING EFFICIENCY.

As the various types of heating used in electric-furnace work have been outlined, and as the most important factors connected with the use of the electric current for this purpose have been presented, the bearing of these factors on the efficiency of the furnace will now be considered.

INDUCTION CURRENTS.

SELF-INDUCTION.

As previously stated, the strength and direction of an alternating current are continually changing—twice during each period or cycle it increases from zero to a maximum and then decreases to zero again. Owing to this fact, a conductor carrying alternating currents is surrounded by an alternating magnetic field, which, as has been shown, induces currents (electromotive force) in all conductors within the field. As the conductor carrying the alternating current necessarily lies in the magnetic field, a current is induced within the conductor by its own field. This effect is known as self-induction, and the resulting current is known as the self-induced current.

As such a current may cause considerable loss of power under certain conditions, it is well to understand these conditions and as far as possible avoid them in the construction of electric furnaces.

An induced current is generated in every conductor that is parallel to the main current, hence care should be taken not to short-circuit the conductor carrying the induced current, since this may cause heavy losses of power. For example, in designing a furnace, an iron beam should not be placed in such a position as to cause the conductor to be short-circuited on itself. Likewise the cables and bus bars leading from the transformers to the furnace should be placed close together, for in this way there is no action on closed iron parts, or parts that lie parallel to one another, and thus the magnetic fields, as for example those made by two conductors of a single-phase current, are neutralized. These conditions are of importance only when heavy currents are employed, but heavy currents are usually used in electric-furnace work. One must remember also that currents are induced in all metal parts that are near a conductor.

EDDY CURRENTS.

The currents that are induced in the metal parts of a furnace are called eddy currents. As the metallic parts are good conductors, through which the current may be short-circuited, these parts if improperly placed may become decidedly hot and cause more or less trouble. This is especially true when the metal is magnetic, that is, a good conductor of the magnetic lines of force. For example, in furnaces in which the current is led to the electrodes through electrode holders, making these holders of cast iron or steel will cause considerable loss. For this reason the holders, which are generally water-cooled, are made of copper or brass, neither of which is magnetic.

Another method of lessening eddy-current losses is to greatly subdivide the metallic parts in which eddy currents are likely to occur, as is done, for example, in transformers and in armatures of dynamos.

HYSTERESIS.

There is also another loss from what is known as hysteresis, the lag of demagnetization. This loss occurs in magnetic conductors having considerable cross section and is due to the constant magnetizing and demagnetizing influence of the alternating current. Therefore, in furnace construction, the electrical conductors should not be sur- ded by parts that are good magnetic conductors.

LAG.

If an electric current be passed through a coil of wire, the current does not immediately reach its maximum value, but does so only after a certain time has elapsed. In other words, the current lags behind the voltage, and this is known as the lag of the current.

ELECTROMECHANICAL FORCES IN THE INDUCTION FURNACE.

The nature and effect of the mechanical forces of electric origin in the bath of the induction furnace, although at present well understood, are still to many a source of apprehension in the design and operation of this type of electric furnace. These electromechanical forces, which often are of considerable magnitude, are of two kinds: (1) Attracting, due to the mutual attraction of current-carrying elements within the bath, similar to the attraction of two parallel conductors carrying current in the same direction; and (2) opposing, due to the repelling action between the bath and the primary winding, similar to the repelling action of two conductors carrying current in opposite directions.

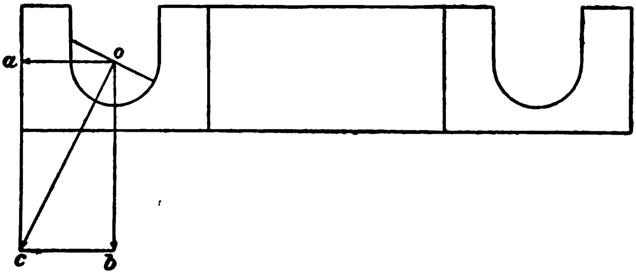


FIGURE 12.—Cross section of the bath of an induction furnace, showing effect on surface of bath of the resultant of the different forces acting.

PINCH EFFECT.

Attention was several years ago called to the first of these forces by E. F. Northrup and later by C. Hering, who observed a contraction in the cross section of the bath. The contraction was frequently so pronounced that complete rupture resulted. This phenomenon has since been generally referred to as the "pinch effect."

In figure 12 the circle represents the cross section of a circular conductor. The tendency of the electromagnetic forces of the first class mentioned is to act radially and their manifestation is a mechanical effect, the liquid particles constituting the conductor moving bodily in the direction of the forces. If, by suitable means, the pressure in the bath be measured, it is found to be greatest at the center and least at the periphery. For the pressure at the center of a bath having a circular cross section, the following formula has developed: $P=\frac{I^2}{S}$, in which P is the pressure in dynes per square centimeter, I is the current in c. g. s. units (10 amperes), and S is the cross section of the bath in square centimeters.

Although the formula holds precisely true only for conductors of circular cross section, no great error is involved in applying it to the practical working conditions of the induction furnace.

In the bath of an annular crucible of ideally uniform cross section, this pressure would not produce the contraction known as the pinch effect, but in practice the cross section is never uniform, because of dissymmetry in the crucible, or of deflection of the plane of the crucible from the horizontal, or of the presence in the bath of unmolten nonconducting material, such as floating pieces of ore or brick. Whenever the cross section of the bath is reduced by any cause the pressure is locally increased and the result is a lateral force causing a flow to adjacent areas of lower pressure. An increase in the current will augment this effect and if the current is further increased a limit is reached, when the liquid is "squirted" out from the spot of high pressure faster than it can return, and a break in the circuit results. If the bath is mobile, the circuit will continue to close and open until freezing occurs.

The working limits imposed upon induction furnaces by the pinch effect have been studied and a formula developed, by means of which the critical current values can be calculated approximately. Experience has shown that the pinch effect does not cause difficulty in the operation of large induction furnaces, such as are used in steel making, for in these the values of the currents used are far below the critical points. The pinch effect, however, has thus far made impracticable the melting in an annular crucible of metals of low specific gravity, such as aluminum. Metals of low specific resistance, such as copper, are likewise less amenable to working in induction furnaces of the annular type, because heat generation is a function of the specific resistance, and when the specific resistance is low greater current density is required, which may exceed the critical value for the furnace.

From the standpoint of metallurgists the mechanical effects of the magnetic forces set up in the bath of the induction furnace are of value. The resulting circulation of metal in the crucible assists the heating by increasing convection and accelerates chemical action by bringing the reacting substances into more intimate mixture. Appreciation of these advantages has inspired efforts to design on the induction principle a furnace in which the danger of "pinching" will be eliminated but the desirable effect of increased circulation retained.

Such a furnace has been constructed and although still in the development stage promises speedily to find peculiar and important application in the melting of metals.

CENTRIFUGAL EFFECT.

Electromagnetic forces of the second class are set up between the bath and the primary winding. Their mechanical manifestation in the bath resembles in many respects the effect that would be produced by rotating the annular bath on its axis, and for this reason the name "centrifugal effect" has been given it.

This repelling force between the primary winding and the bath of a single-ring induction furnace is analogous to the repelling forces between the windings of a core transformer, and the theory and calculations for the later forces may be applied to the induction furnace, as the induction furnace is in fact equivalent to a transformer with a short-circuited secondary.

In addition to the centrifugal force mentioned a second force acting upon the bath is gravity. In figure 12, representing the cross section of the bath of an induction furnace, if *oa* be considered to represent the centrifugal force of electromagnetic origin and *ob* gravity, the surface of the bath must be perpendicular to the resultant force *oc*. As the tendency of the pinch effect is to give the bath a circular cross section, the result of all the forces acting on the bath is to give its cross section the form shown on the left. In large furnaces operating at full load the surface of the bath is inclined about 30° to the horizontal.

There is no danger of the circuit breaking as a result of the centrifugal force on the liquid bath. When a solid starting ring breaks, however, the break is invariably due to the centrifugal force, which has exceeded the tensile strength of the ring.

The centrifugal effect, like the pinch effect, tends to eliminate inclosed gases by compression of the bath against the outer wall, and also causes circulation at right angles to the direction of the bath. In some large furnaces, such as the Frick and the Hiorth, sections of the primary winding are placed above and below the bath, thereby moderating the circulation and removing the danger of the starting ring being broken.

POWER FACTOR.

MEASUREMENT OF POWER FACTOR.

The power supplied to a furnace in watts is for a direct current the product of the number of amperes and the number of volts, whereas for an alternating current it is the product of the number of amperes and the number of volts, multiplied by a factor known as the power factor, which varies with the construction of the furnace, as explained later. In this connection, it may be stated that alternating current is used almost entirely in furnace work, for two reasons. First, almost all large electric-power installations generate alternating current, and hence at most places only alternating current is available for furnaces, unless the current be transformed by means of a motor generator set into direct current. Moreover, a direct current is not necessary, and in fact is undesirable in furnace work, because it exercises an electrolytic action on the metals produced.

The power (watts) delivered to the furnace may be kept constant by keeping the voltage low and the amperage correspondingly high, or by keeping the voltage high and the amperage correspondingly low. If, for example, a furnace be built for 50 kw. (50,000 watts) at 50 volts, if the power factor were neglected, the ammeter would show 1,000 amperes; in other words, the number of watts divided by the number of volts gives the number of amperes. For currents of large amperage large conductors are required, thus increasing the cost of cables, transformers, electrodes, and other equipment. The use of a high voltage, although economical, is generally impractical, because most furnaces have a low electrical resistance. For example, in the Swedish and California types of electric iron-reduction furnaces the resistance is in the neighborhood of 0.01 ohm, and the voltage used varies from 40 to 80 volts with a three-phase furnace. With an average load of 500 kw. on each phase, the corresponding number of amperes per phase would be 10,000. Thus it is seen that having to handle electric currents of high amperage is one of the disadvantages of electric-furnace work of this nature.

USE OF OHM'S LAW.

As previously stated, the power used in a furnace, measured in watts, is for direct current the product of the number of amperes and the number of volts, whereas for alternating current it is the product of the number of amperes and the number of volts, multiplied by a factor known as the power factor. If the relations between the alternating and the direct current be compared, it will be found that for the direct current a definite voltage is required to force a current, I, through a resistance, R, and, according to Ohm's law:

$$E \text{ (electrical pressure)} = I \times R$$

In order to force an equal alternating current, I, through a resistance (the resistor, the charge, or whatever is used in a particular case), the fact already explained must be taken into account—that with the alternating current an electromotive force due to self-induction is generated, which is always in the opposite direction to the impressed electromotive force. Therefore instead of the equation being $E = I \times R$, it must be written as $E_r = I \times R$, and as an additional pressure (voltage) is needed to overcome the electromotive force of self-induction, the total voltage necessary for an alternating current is $E = E_r + E_1$.

In other words, the voltage of an alternating-current voltage has two different pressure waves, and instead of the power P on the furnace being expressed by the equation $P = E \times I$, for alternating current the equation is $P = EI \cos \phi$, where ϕ is the angle of lag or lead of current, because, as has been pointed out, the effect of capacity on the circuit is to cause the electromotive force to lag behind the current. Therefore, if the current either lags or leads, the readings of the instruments used for measuring the electric current at the furnace (the voltmeter and ammeter) are not true simultaneous values, and in order to get the true values the product of the number of volts and amperes shown on the instruments must be multiplied by a factor obtained in the manner above stated.

Hence, in an alternating-current circuit the product $E \times I$ is called the apparent power, and can be measured in volt-amperes or kilovolt-amperes, a kilovolt-ampere being equal to 1,000 volt-amperes. The product $EI \times \cos \phi$ indicates the real or effective power and is measured in watts or kilowatts. Inasmuch as the determination of the cross section of an electrical conductor depends on the strength of the current the conductor is to carry, and the current strength decreases with an increasing power factor, provided the voltage and power remain unchanged, it is of course desirable to obtain the highest power factor.

As the ammeter and voltmeter on an alternating circuit do not in any way indicate what the power factor is, a special meter is used called the wattmeter, which indicates the watts or kilowatts directly. One kilowatt equals 1,000 watts.

Because of the facts stated, it is evident that in designing a furnace a high-power factor should be sought.

POWER CIRCUITS.

As previously stated, most large power circuits are three phase, which means that three lines are needed to conduct the current from the source of supply to the point where it is used, whereas with single-phase current only two lines are necessary.

In using a single-phase current the connecting of the electrodes to the source of supply is a simple matter, as may be seen by referring to figures 1, 2, 3, and others. If, on the other hand, three-phase current be used, three different types of connections may be used, as shown in figure 13.

REGULATION OF THE ELECTRIC CURRENT.

The current in an electric furnace may be regulated in one of two ways, as outlined below:

1. Inasmuch as the electrical resistance in a furnace changes with the height at which the electrode is kept above the charge or bath, the electrode may be made movable and then raised or lowered as may be necessary.

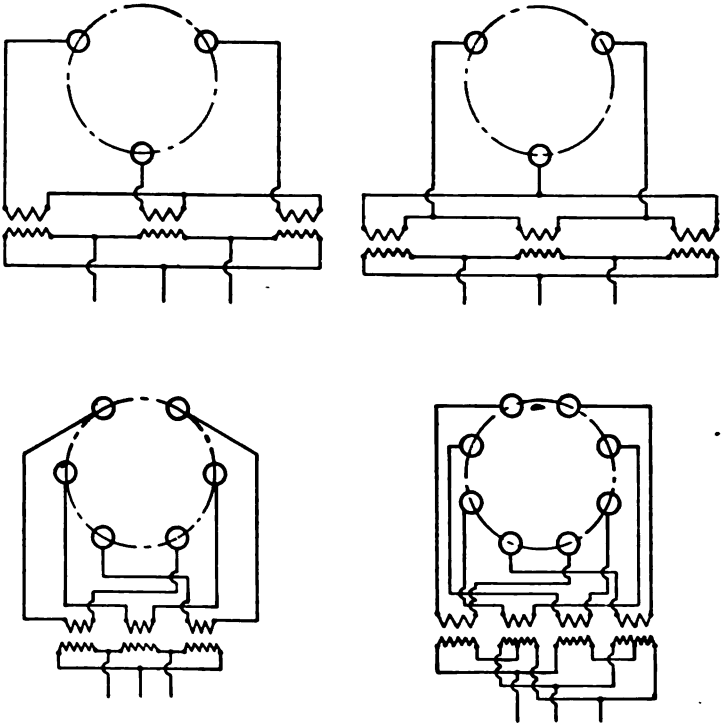


Figure 13.—Different types of electric furnace connections.

2. The electrode may be kept stationary and the voltage varied by means of variable voltage transformers.

The first method is employed in operating steel furnaces of the Héroult, Girod, and Electro-Metals type. The raising and lowering of the electrodes may be done by hand or by means of electric motors controlled by instruments regulated by the voltage of the furnace in such a manner as to keep the load constant.

The second method is used on the Swedish and California types of furnaces.

Van Norden[a] describes the electric control of the electric iron smelting furnaces of the Noble Electric Steel Co. at Heroult, Cal., as follows:

> Electric control is through a switchboard, there being a panel for each furnace. As the current and power factor in each phase must be under observation at all times during operation, separate meters are installed in each phase. The requirements for one panel are three ammeters, three voltmeters, three wattmeters, three power factor meters, and three recording wattmeters. These are mounted across the panel in rows of three each. Under the first four sets named are three handwheels to control the voltage variation, and under these, three switches which control the entire load, and still under these are the recording wattmeters.
>
> For operating the voltage control and the main circuit breakers there is a 7½-kilowatt motor-generator set, comprising a 125-volt direct-current generator, directly connected to a 10-horsepower induction motor. This set has a small panel-board mounting, a circuit breaker, ammeter, voltmeter, and two single-pole knife switches. * * * In the event that line voltage should fall, or for any other cause, the direct current supply should become deranged, there is a * * * storage-battery set, having a capacity of 7½ kilowatts which may be instantly switched in, and thus prevent the furnace from cutting out in the case of low voltage.

ELECTROLYSIS.

Although the electrolytic or decomposing effect of the electric current finds more extended application in the electrochemical industries than it does in the production of metals from their ores, it is nevertheless more or less used for the latter purpose, especially in the production of aluminum, and for that reason is briefly discussed at this point.

ELECTROLYSIS OF WATER.

The electrolysis of water is a familiar example of the decomposing effect of the direct electric current. By the use of such a current water can be resolved into its component elements, hydrogen and oxygen. In order to do this the terminals of a direct electric current are inserted into a dish or glass containing the water. The positive terminal is known as the anode, and the negative as the cathode. When the current is turned on, it passes through the water from the positive to the negative terminal (from the anode to the cathode), and electrolyzes or decomposes the water. The hydrogen is liberated at the cathode, or negative terminal, which may be designated the negative electrode, and the oxygen is liberated at the anode or positive electrode.

ELECTROLYSIS OF COPPER SULPHATE.

Similarly, if a direct current be passed through a solution of copper sulphate, which, in such case, is termed the electrolyte, copper will be deposited at the cathode and sulphuric acid gas will be given off at the anode. In refining cast copper, the anode is made of the impure metal, and a solution of copper sulphate is used as the electrolyte. Under the action of the electric current, the copper anode dissolves, and pure copper is redeposited at the cathode. Any substances other than copper in the anode, are, if the current is properly regulated, liberated and collect on the bottom of the tank containing the electrolyte.

---

[a] Van Norden, R. W., Jour. Elect. Power and Gas, vol. 30, 1913, p. 1.

PREREQUISITES OF AN ELECTROLYTE.

In electrolyzing a solution of copper sulphate, the water, which is a more stable combination than copper sulphate, is not broken up, as the current acts on the least stable compound. On the other hand a solution of aluminum sulphate is more stable than water, and hence an electric current would decompose the water and not the aluminum sulphate. Such being the case, the following prerequisites must be observed in preparing an electrolyte, namely: For the substance to be electrolyzed a solvent that is more stable than the salt, or the pure salt in a state of fusion, must be employed. Aqueous solutions must be avoided when the water can react with the metal produced. For example, an aqueous solution can not be used in the production of metallic sodium, because water reacts with sodium, forming caustic soda and hydrogen.

ESSENTIAL DETAILS OF ELECTROLYSIS.

In electrolytic work, the quantity of metal produced depends chiefly on the quantity and voltage (electrical pressure) of the current that is passed through the electrolyte, thus bringing about a definite amount of decomposition which is always the same for the same solution. The quantity of metal that will be liberated by electrolysis per unit of time by a given current may be calculated in the following manner: If a current of 1 ampere be passed through acidulated water for a period of one second, 0.0104 milligram of hydrogen will be liberated. Therefore, the quantity of metal obtainable by passing a like current through a copper sulphate solution may be determined from the equation $\frac{C \times W}{V} = x$, in which C represents the constant 0.0104, W the atomic weight of the metal, and V the valency of the metal in the particular solution. However, the quantity of metal shown by this calculation is not always obtained, owing to the secondary reactions that take place, such as the liberation of hydrogen instead of the metal, the redissolving of metal in the electrolyte, and the leakage of the current. For this reason, what is termed current efficiency, by which is meant that proportion of the current that is effective in liberating the metal, has to be taken into consideration.

In order to pass a stated quantity of electrical energy through a given solution in a stated time, the electrical current must be kept at a definite voltage, or pressure, for that particular solution. Below this pressure, or voltage, electrolysis will not take place.

Inasmuch as the current in passing through the electrolyte meets with resistance, heat is generated, the quantity of which is proportional to the square of the current and to the resistance of the electrolytic cell. As this generation of heat represents the expenditure of electrical energy, the higher the temperature, the less efficient is the decomposing effect of the current. However, in the electrolysis of fused salts or compounds, the heat generated through the resistance of the electrolyte to the passage of the current serves to keep the electrolyte fused and so is of use instead of being wasted.

The nature and the composition of the anode are of great importance in electrolytic work. If possible the anode should meet the following seemingly contradictory requirements: The anode material should be insoluble in whatever is liberated in contact with it as the result of the electrolytic action of the current, but if the material is soluble, it should be inexpensive, for it will be dissolved in proportion as the metal is deposited. In the manufacture of aluminum, the carbon electrodes (the anodes) are consumed by the oxygen liberated by the decomposition of the alumina of the electrolyte into aluminum and oxygen, and the weight of electrodes consumed about equals the weight of aluminum produced. On the other hand, as regards the amount of energy needed to break up a given weight of compound into its elements, more voltage is required for an anode that does not dissolve than for one that does.

In electric-furnace work, electrolysis is involved in reducing metals from ores when the metal is present in the form of a salt or a mixture of salts which must be fused and the metal deposited from the fused mixture by a direct electric current.

MECHANICAL CONSTRUCTION OF FURNACES.

The electrical side of the subject has been briefly discussed in the foregoing pages. The factors that must be taken into consideration in the actual construction of an electric furnace will now be noted.

FACTORS AFFECTING OUTPUT.

Naturally, in the construction of a furnace, the first matter to be taken into consideration is output. Inasmuch as a small furnace, using a comparatively large amount of power, may produce as much as a larger furnace using a comparatively small amount of power, the nature of the process must be considered in deciding what size of furnace will be employed. Then, too, one must remember that large electric furnaces, large as compared with modern copper and iron blast furnaces, have not been successfully operated as yet, and hence if the desired production is, say, 100 tons or more of metal a day, the size of the unit to be employed will first have to be determined. As regards this point, the facts that should be borne in mind are as follows: (*a*) The relative loss of heat through the walls is less for a large than for a small furnace, and therefore each unit should be as large as may be feasible; but (*b*) in order to reduce the total heat loss the furnace should be as small as possible for the stated output.

In other words, for a given output a smaller furnace is more efficient than a larger furnace, but, as before stated, the nature of the process must be taken into consideration in determining relative economy. As a comparatively large amount of energy is required to keep the temperature of the furnace uniform, it is of course better to employ continuous processes wherever feasible, or to leave as little time as possible between charges if an intermittent process be used.

CALCULATION OF ENERGY REQUIRED.

When the output of the furnace has been determined, the amount of energy that will be required to give this output has to be calculated. In this calculation the following factors have to be taken into consideration: (*a*) The heat available from such chemical reactions during the process as give up heat, that is, as are exothermic. Illustrations of such reactions are the burning of carbon to carbon monoxide, or of carbon monoxide to carbon dioxide, or the formation of a silicate. The other factor is (*b*) the heat that is absorbed during the process. The absorbed heat includes that required to raise the raw material to a smelting temperature, or to a temperature at which the reactions necessary to the process take place, and also the energy that is absorbed in such reactions, as for example, the reduction of iron oxide to iron, of silica to silicon, or of calcium from calcium oxide. Almost all of these changes involve the specific heat, generally the latent heat of liquefaction, and sometimes, too, that of vaporization. Also, allowance must be made for loss of heat by conduction through the furnace walls and through the electrodes. These losses are discussed in subsequent pages.

As a result of these calculations a heat balance sheet of the process may be constructed. The following example[a] will serve to illustrate this point. Let it be assumed that an iron ore is to be smelted and that the calculations for determining the amount of heat available and necessary show that for each ton of metal to be produced 1,053,532 calories must be supplied electrically and that the desired output is 1 ton of metal per hour, then each ton will require $1{,}053{,}532 \div 3{,}600 = 292$ calories per second. The total horsepower required to furnish this heat, $\frac{292 \times 425 \text{ kg. m.}}{75} = 1{,}654$ horsepower.

Which means that theoretically there would have to be supplied to the furnace a constant current of 1,654 horsepower in order to produce 1 ton of pig iron per hour.

---

[a] For further information on the subject of calculations of this kind see Richards, J. W., Metallurgical calculations, 1907, pt. 2, p. 403; and Yngstrom, Lars, The electric production of iron from iron ore: Engineer London), Feb. 26, 1900, p. 206.

CURRENT AND VOLTAGE NECESSARY.

After the amount of current necessary to carry on the process has been ascertained, the voltage at which the current is to be supplied may be determined. The choice of voltage is governed largely by the construction of the furnace. Theoretically it is best to have the voltage as high as possible, but practical considerations generally prohibit the use of a high voltage, and hence a comparatively low voltage is used in electric-furnace work. For example, the voltage used for an iron-reduction furnace ranges from 40 to 80 volts, 50 volts perhaps being the average. In the case of the Héroult steel furnace 90 volts is used for the three-phase furnace at South Chicago, whereas for a Héroult single-phase furnace a voltage of 100 to 110 volts is ordinarily used. In an induction furnace the primary voltage may be as high as 3,000, whereas in the Moissan arc furnace it is about 110. As a rule, in arc furnaces the arc should be as long as other considerations permit.

PROPER SIZE OF INTERIOR OF FURNACE.

Of course waste space in the interior of a furnace greatly diminishes efficiency. On the other hand, it is sometimes necessary to allow for what may seemingly be waste. For example, in the Swedish electric iron-reduction furnace the roof of the crucible is so constructed as to allow a gas space between the surface of the charge and the roof. In this way the roof, at the point where the electrodes enter it, is somewhat protected from the heat developed in the charge. Or it may be found best to allow part of the material forming the charge to chill along the walls of the furnace in order to protect the walls. In such instances, however, the material must be considered as a part of the wall of the furnace and not an available part of the interior of the furnace. As a rule the interior of the crucible of the furnace should be made as small as practicable.

The interior dimensions of some furnaces in actual practice are given below:

Dimensions of three furnaces.

Type of furnace.	Location.	Product.	Capacity.	Power.	Internal dimensions.			Thickness of lining.			Diameter of electrodes.
					Length.	Width.	Depth.	Ends.	Sides.	Roof.	
			Tons.	*Kilowatts.*	*Ft. in.*	*Ft. in.*	*In.*	*In.*	*In.*	*In.*	*In.*
Héroult.	Braintree, England.	Steel..	2.5	300	[a]4 2 [b]5 2	1 8 2 7	31	14	12	12	14
Do..	South Chicago, Ill.	...do..	15	1,200-1,500	(c)	(c)	[d]36	......	18	12	14
Girod...	Ugine, France.	..do..	2.5-3	300	[a]3 [b]6	3 6	31	......	......	......	....

[a] Bottom. [b] Top. [c] Circular; diameter, 120 inches. [d] Approximate.

PROPER SHAPE OF CRUCIBLE.

The next item to be taken into consideration after the cubic contents of the crucible has been determined is the shape of the crucible. Theoretically, the spherical form is best so far as heat losses and general efficiency are concerned, but here, as in the determination of all points that have to be considered in the construction of a furnace, the special requirements to be met rather than the theoretical considerations will have the most weight.

TYPES OF FURNACE LININGS.

The kind of refractories that will be used in the lining of the furnace will depend on the nature of the product—that is, whether it is to be a solid or a liquid, and whether it will be acid, basic, or neutral in its chemical action.

ACID REFRACTORIES.

Silica.—Silica sand, either as such or made into brick, is most commonly used when a siliceous refractory material is desired. A typical analysis of a silica sand is as follows:

Typical analysis of silica sand.

	Per cent.
Water	0.24
Silica	97.25
Alumina and iron oxide	.16
Lime	.08
Alkalies	.36
Magnesia	.39
Loss on ignition	.36

When the sand is made into bricks a small percentage of lime or some other similar substance is used as a binding material. By reason of the binder the melting point of the bricks is lower than that of the pure sand, and bricks made of pure fused quartz would be more refractory. There is a possibility that such bricks may soon be available for use in furnace linings. A good silica brick should not contain less than 95 per cent of silica.

Dinas brick.—The name Dinas was applied originally to a brick made in Wales, from a pure sandstone that contained as much as 98.3 per cent and not less than 96 per cent silica. A Dinas brick that contains 98 per cent silica contains about 0.72 per cent alumina (Al_2O_3) and 0.10 to 0.20 per cent each of iron oxide (Fe_2O_3), lime (CaO), and alkalies.

Although Dinas bricks are capable of withstanding high temperatures, they have a coarse texture, are rather friable and brittle, and do not withstand abrasion. Two grades of these bricks are used in the

United States, one being imported and the other made in domestic plants. An analysis [a] of an American brick is as follows:

Analysis of an American Dinas brick.

	Per cent.
SiO_2	94.07
Fe_2O_3 and Al_2O_3	3.66
CaO	1.39
MgO	.19

The Dinas bricks differ from ordinary silica bricks in the binder used. In many silica bricks the binding material is clay, whereas in the Dinas bricks, as before mentioned, the binding material is a lime silicate.

Ganister.—The term "ganister" is used loosely. According to Fulton [b] it means a siliceous material of about the following composition: Quartz, 83 per cent; clay, 13 per cent; and impurities and moisture, 4 per cent. Any siliceous material containing silica and clay in the above proportions may be used as ganister, provided it does not contain fluxing ingredients enough to lower materially the refractoriness of the product. Ganister can be made by mixing a highly siliceous material with enough clay to act as a binding material. It is not used as bricks, but as loose material, which is tamped into place as in furnace bottoms.

Fire clay.—Fire clay is sometimes classed as an acid refractory and sometimes as a neutral one, owing to the fact that in different clays the proportions of siliceous and aluminous contents, which together should constitute 92 to 98 per cent of the clay, differ widely. The refractoriness of a clay depends upon the proportion of those constituents which tend to lower the melting point of the clay. For the most part these constituents are ferric oxide, titanium oxide, lime, magnesia, and oxides of sodium and potassium. Of these constituents, ferric oxide probably lowers the refractoriness of the clay more than any other, especially if the clay also contains carbonaceous matter. Owing to the presence of the mineral, kaolinite fire clays are plastic when mixed with a comparatively small proportion of water, and for this reason are easily molded into bricks of any required shape. In practice it has been found that the texture of a brick governs to a certain degree its refractoriness. For instance, a brick made of a fine-grained clay is not as refractory as one made from a clay in which there is a large proportion of coarse particles, even if the two clays have the same chemical composition. The refractoriness of a fire brick is much increased by the coarseness of texture; that is, if a fire brick be composed of a ground mass of fine grains in which are embedded comparatively coarse grains, the greater the percentage of coarse grains the more refractory will be the brick. Fulton [a] has shown that the principle involved is the same as that governing the formation temperature of slags.

---

[a] Fulton, C. H., Principles of metallurgy, 1910, p. 334.

[b] Fulton, C. H., op. cit., p. 335.

BASIC MATERIALS.

Lime.—One of the most abundant basic refractory materials, and theoretically one of the best, is lime (CaO), which has a melting point of about 1,900° C. Practically, however, pure lime is of no use as furnace lining because of the rapidity with which it slakes when exposed to air. It has been found,[b] however, that if the lime be fused, it will resist moist air for several days, whereas ordinarily it will do so for only a few hours.

Magnesia.—Probably the most important of the basic refractory materials is magnesia (MgO), which, in electric furnace work, is used mostly in the form of brick. The bricks are made by mixing 90 per cent of thoroughly burned magnesite with 10 per cent of incompletely burned material, which is added for the purpose of causing the bricks to set. The mixture is then molded into shapes and burned.

The bricks are dense and hard, and can be heated up to 1,800° or 1,900° C. The objections to the use of magnesia bricks are as follows:

1. They are good conductors of heat, and when hot become fairly good conductors of electricity.
2. They expand somewhat on heating and spall or flake off when subjected to sudden changes of temperature.
3. They are liable to go to pieces if subjected to a heavy load when hot.
4. They are liable to shrink and crack when heated to high temperatures.

Electrically calcined magnesite.—If the magnesite be calcined in an electric furnace, where it is subjected to a much higher temperature than is the ordinary calcined magnesite, it is less liable to shrink and crack, and does not absorb carbon dioxide gas as readily as does ordinary calcined magnesite. Fitzgerald [c] states that several tons of magnesia have been electrically calcined and tested in a great variety of furnaces, and in every case excellent results have been obtained. He also states that a resistance furnace has been developed that will calcine the magnesite to the desired degree.

Bauxite.—Bauxite is used for making both basic and neutral refractory linings, the nature of the chemical action depending largely upon the composition of the bauxite used. As compared with magnesia, bauxite, which is extensively mined as an ore of aluminum, is cheaper. It can be made into a very hard and tough brick, the tensile strength of which may be as much as 10,000 pounds per square inch. When used for making brick, bauxite has to be selected with care, as it must contain enough silica and iron oxide to make a firm brick through the combination and incipient fusion of the two oxides. On the other hand, it must not contain too much silica, as that lowers its refractoriness. If the brick is to be used as a basic refractory material, the silica content should not exceed 12 per cent.[a] The composition of a bauxite suitable for brickmaking is approximately as follows:[b]

---

[a] Fulton, C. H., Principles of metallurgy, 1910, p. 272.

[b] Fitzgerald, F. A. J., Refractories: Met. and Chem. Eng., vol. 10, 1912, p. 129.

[c] Fitzgerald, F. A. J., Loc. cit.

Approximate analysis of bauxite for making brick.

	Per cent.
Silica (SiO_2)	4 to 7
Iron peroxide (Fe_2O_3)	3 to 5
Alumina (Al_2O_3)	60
Water (H_2O)	30

Although bauxite is very refractory, it must be almost completely calcined, a difficult attainment, before it can be used for furnace lining or else it will shrink excessively at furnace temperatures. Calcination causes it to lose its combined water and thus destroys its plasticity. Because of these disadvantages it is seldom used in electric furnaces. At Braintree, England, the Lakes & Elliott Foundry Co. have used bauxite bricks in the construction of the roof of their Héroult steel furnace. The roof lasts from 14 to 28 heats. The short life of the roof, as compared to the life of the roof of other furnaces, is doubtless due to the fact that the construction of the furnace was such as to prevent the usual amount of radiation.

NEUTRAL LININGS.

Carbon.—Carbon is neutral and is one of the most highly refractory substances known. It is generally used in the form of lamp black or retort carbon.

Although carbon is capable of withstanding the action of slags, it has the drawback of being readily attacked by metals which have a strong affinity for it. For this reason carbon in the form of brick, or rammed with tar, has never come into practical use in open-hearth furnace bottoms, but the bottoms of furnaces used for making ferro-alloys, such as ferrochrome and calcium carbide, are nearly all made of carbon. Moreover, these bottoms are as durable as any other part of the furnace, in fact more so. At the works of the Keller-Leleux Co., Livet, France, the furnaces, when once charged and started, are run continuously for an average period of a couple of years. The company states that the period may be made as long as four years.[c] Also, when, in 1912, one of the authors of this bulletin visited the plant of the Meraker Electric Smelting Co., Kopperaaen, Norway, he was informed that one of its furnaces, which have carbon bottoms and are used in the production of ferrochrome and calcium carbide, had been running continuously for 22 months and the other for 6 months. That the carbon bottoms in these furnaces are not destroyed is probably because enough carbon is added to the charges to satisfy the alloys produced and because the bottoms are not exposed to oxidation.

---

[a] Fulton, C. H., Principles of metallurgy, 1910, p. 340.

[b] (Editorial), Met. and Chem. Eng., vol. 8, 1910, p. 107.

[c] Copeman, S. M., Bennett, S. R., and Hahe, H. W., Manufacture and transport of ferrosilicon: Met. and Chem. Eng., vol. 8, March, 1910, p. 135.

The bottoms are made of lampblack or retort carbon, which is mixed with tar, heated, and then rammed into place.

Chromite.—Chromite, usually termed chrome iron ore, is a sesquioxide of chromium. A typical analysis of chromite is as follows:

Typical analysis of chromite.

	Per cent.
Sesquioxide of chromium (Cr_2O_3)	38 to 40
Alumina (Al_2O_3)	24.5
Iron peroxide (Fe_2O_3)	17.5
Silica (SiO_2)	3.25
Magnesia (MgO)	15.0

Although chromite is extremely infusible, this property has the disadvantage of making its thorough sintering difficult. For this reason, chromite, although not affected by comparatively high temperatures, will not withstand mechanical erosion, and hence is not suited to furnace bottoms. It is well suited to the construction of furnace walls above the slag line, where they are not subjected to mechanical erosion of any sort.

Alundum.—Alundum is made by purifying and fusing bauxite in an electric furnace. Two forms, a white and a brown, the former being the purer, are on the market. The melting point of white alundum is between 2,050° and 2,100° C. and that of the brown product is not more than 50° lower.[a]

Alundum has been formed into bricks which were used for making the roof of an electric furnace. In this same furnace a roof built of silica brick was destroyed in 5 or 6 hours, whereas the alundum roof, at similar temperatures, lasted 40 or 50 hours. However, as pointed out by Fitzgerald,[b] although alundum bricks are capable of withstanding high temperatures when used in the construction of the roof of an electric steel furnace, they are not entirely suited for such construction for the following reasons:

1. The lime vapors that rise from the intensely heated basic slag in the furnace react with the alundum brick and in time destroy the roof.

---

[a] Fitzgerald, F. A. J., Refractories: Met. and Chem. Eng., vol. 10, March, 1912, p. 129.

[b] Fitzgerald, F. A. J., Idem.

2. Although alundum bricks outlast silica bricks, yet because of their extra cost their use in electric-furnace construction is not warranted.

Carborundum.—When sand, sawdust, and coal are heated together in an electric furnace at a high temperature, a carbide of silicon is formed which is known as carborundum. This carborundum may be crushed and made into brick by mixing the crushed product with a suitable binder, such as tar, glue, or sodium silicate. The fusing point of carborundum itself is about 2,200° C. Three samples of carborundum brick were recently submitted to the Bureau of Standards for examination, and the melting point of all three proved to be about 1,720° C. The failure of these bricks was due to the destruction of the binder, not to the fusion of the material as a whole. After the binder is destroyed, the remaining material has too little strength to last as a brick, often crumbling from its own weight. The binding material is largely vaporized, perhaps after a chemical reaction with the carborundum, as is shown by a considerable loss in weight and by the remaining material containing practically nothing but carborundum. All three samples behaved in practically the same way under test. When they were heated in a vacuum, loss of the binding material became noticeable at about 1,725° C. and became rapid at 1,750° C. When the samples were heated at atmospheric pressure, loss occurred at those temperatures, but it did not become rapid until a higher temperature was reached. At 1,860° C. considerable changes occurred in half an hour.

Crystolon.—Crystolon is a trade name given to a crystalline form of carborundum made by the Norton Co. Being crystalline, it is made at a higher temperature than the amorphous form and is more refractory. The Norton Co. and the Fitzgerald & Bennie laboratories have done a great deal of experimenting with crystolon as a refractory material. Fitzgerald[a] describes the results of the experiments as follows:

> Under ordinary conditions crystolon is infusible, but when heated to a sufficiently high temperature in a reducing or neutral atmosphere it is decomposed, silicon vaporizing and the carbon remaining behind as graphite. If heated to a sufficiently high temperature in a strongly oxidizing atmosphere, slow oxidation occurs, the carbon burning to carbon monoxide and the silicon forming silica. The latter appears to form a protective coating which prevents further oxidation, or at least prevents it from proceeding rapidly.

Fitzgerald[b] has patented a method for making crystolon into any desired form without the use of a binding agent. He mixes finely pulverized silicon carbide with some temporary binder, such as a solution of glue or dextrine, molds the mixture into the desired form, and then heats it in an electric furnace to the temperature at which silicon carbide is formed. This causes a crystallization or recrystallization of the silicon carbide, and a strong, very refractory article is obtained.

---

[a] Fitzgerald, F. A. J., Refractories: Met. and Chem. Eng., vol. 10, 1912, p. 129.

[b] Fitzgerald, F. A. J., U. S. patents 650,234 and 650,235.

As one of the greatest drawbacks to the use of the electric furnace in metallurgy has been the difficulty of maintaining the roof of the crucible, the possibility of using crystolon bricks in roofs is most important, and it is to be hoped that the material will prove satisfactory for this purpose.

SUITABLE REFRACTORIES.

The selection of a suitable refractory for electric furnaces is often difficult. After decision has been reached as to whether an acid, basic, or neutral refractory is desired, the next step is to determine which may be the best refractory under the conditions to be met.

Owing to defects in the process of manufacture, the melting point of a brick is not always a measure of its refractoriness. For example, the use of fire-clay brick as a refractory may be contemplated, and two samples may be submitted for examination. One is found to have a lower melting point than the other, and so it may be said to be less refractory, but in service the one with the lower fusion point may be found to last three to five times as long as the one with the higher fusion point. If the structure of two such bricks be examined, the more durable brick will probably show a dense stony-like structure, in which the component grains are firmly held by the bond, whereas the one with the higher fusion point will probably show a crumbly fracture. By reason of these structural differences in the bricks the one with the lower fusion point wears away slowly, whereas the other, as soon as its surface is worn off, falls to pieces. The composition of the latter brick is correct, but the brick was improperly made. For this reason, in the selection of a fire brick its analysis and fusion point are not reliable indices of its refractoriness. As Rigg[a] has pointed out, the properties possessed by a product that may be properly regarded as refractory may include any or all of the following, according to the conditions of service:

1. Absolute infusibility at the highest working temperature.
2. Complete absence of deformation and shrinkage under working conditions.
3. Mechanical strength.
4. Complete resistance to penetration of vapors, slags, etc.
5. A chemical composition fitted to withstand as completely as possible the corrosive action of the substances to which the bricks are exposed.
6. Equality and fixity of form and dimensions.

---

[a] Rigg, Gilbert, Defects in refractory brick and their causes: Met. and Chem. Eng., vol. 8, May, 1910, p. 237.

As all of these properties depend on the care with which the bricks are manufactured, as well as on their composition, there is obviously a good reason for purchasing bricks from firms whose reputation is well established and who are able, by reason of their experience, to turn out a product that will meet the requirements mentioned by Rigg.

It is well to remember that the structure of a brick—that is, whether it is porous or not—has a great deal to do with its fusion point, if it is to be exposed to furnace gases or slags. Especially is this true of slags; for, obviously, if the brick be porous, the slag will penetrate the pores of the brick and will likely act as a flux for its constituents. Rigg cites from his own experience an example in point. The melting point of a fire-clay mass exposed to a penetrating slag fell from over 1,700° C. to 1,400° C., although, except for a coat of glaze, the mass appeared unchanged. Under the microscope the filling of the pores by slag was plainly visible.

MELTING POINTS OF REFRACTORY MATERIALS.

The following table shows the melting points of some of the most important refractory materials used in furnace construction:

Melting points of important refractory materials.

Name of substance.	Melting point.		Chemical nature.
	° C.	° F.	
Fire clay	1,400-1,800	2,250-3,300	Neutral
Silica brick	1,700-1,800	3,092-3,272	Acid
Silica, pure	1,830	3,326	Do.
Lime	2,040	3,704	Basic
Magnesia brick	2,000	3,632	Do.
Alumina	2,100	3,844	Neutral
Carborundum	2,220	4,060	Do.
Carbon	[a] 3,700	[a] 6,756	Do.

[a] Boils.

In Technologic Paper 10[a] of the Bureau of Standards the melting points of various bricks are given, as follows:

Melting points of various bricks.

Kind of brick.	Melting point.	
	° C.	° F.
Fire clay	1,555-1,725	2,863-3,169
Bauxite	1,565-1,785	2,881-3,277
Silica	1,700-1,705	3,092-3,101
Chromite	2,050	3,754
Magnesia	2,165	3,993

[a] Kanolt, C. W., Melting points of fire bricks: Tech. Paper 10, Bureau of Standards, 1912, p. 16.

As pointed out in the paper by Kanolt above mentioned, "it does not seem possible to establish any very definite relation of a fire brick to its melting point. Since the bricks contain about eight different constituents in quantities sufficient to affect the melting point, and since the melting point may also be affected by lack of homogeneity in the material, it is obvious that a prediction of the melting point upon the basis of a chemical analysis would be uncertain."

In brief, it may be said that in the construction of an electric furnace the choice of the refractory material depends on its capability to withstand fusion in the walls and the crucible of the furnace when subjected to the action of the solids, liquids, and gases that are employed in connection with or are produced at the working temperature of the process.

PROPER THICKNESS OF FURNACE WALLS.

When the kind of refractory material that will be best suited to the furnace has been determined, the next item is the most desirable thickness of the walls of the furnace, especially of the crucible. This detail is of much importance because the efficiency of an electric furnace depends largely on the proportion of the heat value of the electrical energy that is utilized in heating the contents of the furnace. This matter is especially important in the electric furnace, because the electric energy used in heating the furnace is generally much more expensive than are the fuels similarly used. On the other hand, as has been pointed out, the heat supplied to a combustion furnace is largely carried away by the escaping flue gases, whereas in the electric furnace this loss does not occur. Hence in the construction of the electric furnace the main considerations are the heat conductivities of the furnace materials and the ratio of heat loss per unit of volume.

Naturally, the heat loss per unit of volume depends largely on the heat conductivity of the materials that are used in the construction of the furnace.

HEAT CONDUCTIVITIES OF FURNACE-WALL MATERIALS.

In the tabulation following are given the heat conductivities of various refractory materials.[a]

---

[a] Stansfield, A., The electric furnace, 1907, p. 57.

Heat conductivities of furnace materials.

[In C. G. S. units.]

Material.	Temperature. ° C.	Conductivity.
Fire-clay bricks	0- 500	0.00140
....do	0-1,300	.00310
Alumina bricks	0- 700	.00204
Magnesia bricks	0-1,300	.00620
Lime	20- 98	.00029
Carborundum sand	18- 98	.00050
Quartz sand	18- 98	.00060
Fire-brick dust	20- 98	.00028
Infusorial earth	17- 98	.00013
....do	0- 650	.00038

In connection with the conductivity figures Stansfield[a] remarks as follows:

> The figures indicate the number of gram-calories of heat that would pass in one second through a centimeter cube of the material if the hot and cold sides differed in temperature by 1 degree centigrade. The best conductivity varies with the temperature, being greater at high temperatures, as is shown by the first two and the last two items in the list. The figures represent the mean conductivity for the range of temperature indicated, and were probably obtained by measuring the flow of heat through a wall of definite thickness and area, the two sides of which were maintained at the temperatures mentioned. It will be understood that a material having a high conductivity for heat, as shown in the table, would, if used in the construction of a furnace wall, allow a considerable amount of heat to escape and be wasted.

PROPER VOLUME OF CRUCIBLE.

After the proper refractory material for use in the construction of a furnace has been selected, it is necessary to determine whether the laboratory or crucible of the furnace has the proper volume, for the latter is largely governed by the heat conductivity of the materials used in the construction of the crucible, and likewise the degree of heat insulation possible or feasible. On the other hand, it may be necessary to provide for carrying away heat from some parts of the furnace that may be exposed to corrosive slags or to a very high temperature. In order to bring this about, air cooling or water cooling may be adopted.

INSULATION DESIRABLE.

If it be desirable to insulate the walls of the furnace, the degree of insulation desirable must be determined. To effect perfect insulation would be, as pointed out by Hering,[b] to surround the furnace walls with a material that at each point has the same temperature as that of the adjacent point of the conductor. In attempting to obtain perfect insulation, it is quite possible to overinsulate, and thus cause serious damage to the inner walls of the crucible; that is, in certain instances, in order to maintain the inner walls it may be necessary to permit a considerable flow of heat from the inner walls through the outer walls in order to prevent the destruction of the inner walls. The degree of insulation that should be attempted can be determined only by careful calculation and experimentation. The following table of insulating values is given by Snyder.[a]

---

[a] Stansfield, A., loc. cit.

[b] Hering, C., The thermal insulation of furnace walls: Met. and Chem. Eng., vol. 10, February, 1912, p. 97.

Thermal conductivity of refractories.

D—Degrees centigrade required to force a heat flow of 1 kilowatt per square foot through 1 inch of thickness of the material. T—Temperature at hot side of material. t—Temperature at cold side of material.

	t	T	D
Alumina brick	0	700	320
Ashes, wood	0	100	3,840
Brick dust, coarse	0	100	1,680
Carbon, retort, solid	0	100	45
Carbon, electrode	100	400	7.1
Carbon, electrode	100	800	5.2
Carbon, electrode	100	1,200	5.0
Carbon, electrode	100	1,600	4.5
Carborundum sand	18	98	1,300
Cement	0	700	3,800
Charcoal	0	100	2,960
Clinker, small grains	0	700	600
Coke, powdered	0	100	1,480
Copper, metallic	0	30	0.7
Fire brick	0	500	465
Fire brick	0	1,000	155
Fire brick	0	1,300	105
Fire-brick dust	20	98	2,300
Graphite, dust	20	100	1,630
Graphite, electrode	100	400	1.9
Graphite, electrode	100	800	2.1
Graphite, electrode	100	1,200	2.3
Graphite, electrode	100	1,600	2.5
Infusorial earth	17	98	5,000
Infusorial earth	0	650	1,720
Iron, metallic	100	200	4.4
Lime	20	98	2,250
Magnesia, brick, dust	20	100	1,300
Magnesia, brick	0	1,000	92
Magnesia, calcined, Grecian, granular	20	100	1,450
Magnesia, calcined, Styrian	20	100	1,920
Magnesia, calcined, light, porous	20	100	4,100
Quartz sand	18	98	1,090
Silica brick, burned to 1,050° C	0	1,000	330
Silica brick, burned to 1,310° C	0	1,000	210

As has been stated, the ratio of heat loss per unit of volume will be inversely proportional to the dimensions of the furnace when the walls are of equal thickness in each furnace considered. However, as a matter of fact, smaller furnaces generally have thinner walls than do the larger ones, and so, in addition to the heat loss that may be calculated as being inversely proportional to the dimensions of the furnace, the loss of heat through correspondingly thinner walls must be considered. For this reason a large furnace is more efficient than a small furnace; that is, the amount of work performed per unit of electrical energy expended is greater in the large furnace than it is in the small one. As Stansfield[a] has pointed out, "in the extreme case of a small furnace constructed as an exact model on a scale of 1 inch to the foot of a large furnace, the heat loss for each cubic inch of the model would be 144 times as great as from the large furnace, provided, of course, that both attained the same temperature. In other words, if the furnaces were merely being kept hot, no work being done in them, the small furnace would need 144 times as much heat per cubic inch as the larger furnace in order to keep it heated to the same temperature."

---

[a] Snyder, F. T., Flow of heat through furnace walls: Trans. Am. Electrochem. Soc., vol. 18, 1910, p. 242.

In some electric-furnace processes, as making carborundum by the Acheson furnace, it is possible to develop the heat within the charge being heated and to interpose between the hot inner part of the charge and the exterior walls of the furnace enough charge to prevent the exterior walls from being heated. Generally such processes are not continuous and the outside of the charge is not attacked. Naturally the ideal condition in electric-furnace work is to have the process continuous, with the cold charge advancing from the cold exterior part of the furnace to the hot interior part. In this way, of course, the heat radiating from the center of the furnace is absorbed by the cold charge advancing toward the center and is not lost, as it is when it is dissipated through the furnace walls by conduction and radiation. There are mechanical difficulties that interfere with the successful accomplishment of such a scheme, but the nearer it can be approached the greater will be the efficiency of the furnace and the process.

ELECTRODES.

Electrodes serve to carry current into furnaces in which electrical energy is converted in part to heat energy, and as the electrodes are the only avenue through which current is introduced into the charges, it is important that they should neither contaminate the charges nor cause undue waste of energy. They are made in various shapes and sizes to suit particular conditions, but the essential properties are common to all.

An electrode should possess high electrical and low thermal conductivity. It should be resistant to atmospheric oxidation and capable of withstanding handling and temperature changes without danger of breakage.

---

[a] Stansfield, A., The electric furnace, 1907, p. 58.

Electrodes for use in electric furnaces are commonly divided into two classes, carbon and graphite electrodes. Metallic electrodes are employed in rare instances.

Carbon electrodes are made from such materials as petroleum coke (the ultimate residue in the distillation of petroleum), retort carbon (a pure form of carbon deposited in coal-gas retorts), and anthracite.

MANUFACTURE OF ELECTRODES.

The process of manufacture is simple. The material is highly heated in a retort to remove volatile matter, pulverized, mixed with a binder, formed in a press, and baked in a kiln. Graphite electrodes are simply amorphous-carbon electrodes that have been artificially graphitized in an electric furnace, and are thus a product of the electric furnace. Many of the difficulties and annoyances in the operation of large electric furnaces were until recently due to the breaking of poor electrodes. To-day strong electrodes may be had 24 inches in diameter, whereas only a few years ago none over 12 inches had the required strength.

CARBON COMPARED WITH GRAPHITE ELECTRODES.

There is no simple arbitrary rule by which to determine whether a carbon or a graphite electrode is the more suitable for any furnace. It is generally conceded that the graphite is more resistant to chemical action, and in particular to atmospheric oxidation. Moissan determined the temperature at which various forms of carbon begin to oxidize. According to him, amorphous carbon begins to oxidize at a temperature as low as 375° to 490° C., and graphite does not oxidize appreciably below 665° to 690° C. In practice, however, it is less apparent that graphite is inherently superior to carbon electrodes as regards oxidation. That the carbon electrode has the lower heat conductivity has been established by various workers in both experiment and practice. According to Wolgodine's[a] research, the comparative conductivities of graphite and carbon expressed as temperature drop in centigrade degrees per kilowatt flow per square foot through a 1-inch thickness of material, are as follows: Graphite electrode, 2.3; carbon electrode, 4.7.

ENERGY LOSS IN ELECTRODES.

The total energy loss in electrodes is the sum of the loss due to the resistance offered to the passage of the current and the loss by conduction of heat away from the interior of the furnace. This amounts to about 8 per cent of the total input, and when cooling water is used this may account for another 3 per cent. The net efficiency of an electrode, therefore, concerns both its electrical and its thermal conductivities. The electrode efficiency is consequently a physical characteristic for any electrode material, but varies in accordance with the relative importance of the electrical and thermal factors when the quality of the current impressed is varied.

---

[a] Wolgodine, S., and Queneau, A. L., Conductivity, porosity, and gas permeability of refractory mate-ls: Electrochem. and Met. Ind., vol. 7, 1909, p. 383.

EFFICIENCY OF ELECTRODES.

In general, the net efficiency is increased by producing the necessary wattage with as low a current and as high a voltage as possible. The difference in net efficiency of carbon and graphite electrodes need be only a few per cent. As graphite is a better conductor of electricity than carbon, the C^2R loss (C=capacity; R=resistance) is less in a graphite electrode than in a carbon electrode. The conductivity of graphite is usually taken as being four times that of carbon.

CONDUCTIVITY OF ELECTRODES.

The conductivity increases with increasing temperature. Misselt[a] estimates that in general the thermal conductivity of insulating materials decreases at the rate of 1/273 part for each degree above 0° C. Small electrodes can be loaded more than large ones, possibly owing to the greater closeness with which the particles are packed. In view of this fact, modern factories have adopted increasingly larger presses in order to reduce this discrepancy and improve the larger sizes. Again, for the same composition, the specific resistance of round electrodes is much less than that of those with square cross sections. As to the ultimate sizes that can be produced, little can be said. As before stated, although the largest electrodes of sound quality formerly on the market were 12 inches in diameter, it is now possible to get them up to 24 inches without difficulty. Nevertheless, as has been pointed out by one writer on this subject, it may be doubted whether sizes will go on increasing, for the specific conductivity as well as the mechanical strength tends to decrease, whereas the difficulties in handling increase. Attempts have been made to increase the conductivity of electrodes by introducing metals, such as pure iron, with the carbon material while it is being molded. It is stated that the resistance thus formed can easily be reduced to one-half the ordinary value with comparatively little metal.

ESSENTIALS IN USE AND DESIGN OF FURNACE ELECTRODES.

As stated by Hering,[b] the laws of electrode losses are:

1. The combined loss through the cold end of an electrode is equivalent to the sum of the loss by heat conduction alone (when

---

[a] Misselt, Wichelto, Zeitschr. Ver. deut. Ing., June, 1908, p. 90.

[b] Hering, C., Laws of electrode losses in the electric furnace: Electrochem. and Met. Ind., vol. 7, 1909, pp. 442, 514.

there is no current) and half the I^2R loss (I = rate of flow; R = resistance).

2. This combined loss will be least when the loss by heat conduction alone is made equal to half the I^2R loss; the total loss will then be equal to the I^2R loss, and no heat will be conducted from the interior of the furnace.
3. This minimum loss is dependent only on the material, current, and temperature, but not on the absolute dimensions; it merely fixes the relation of the cross section to the length, but leaves a choice of either; hence
4. For economy of electrode material the electrode should be made as short as practical considerations permit.
5. For each material there is a definite minimum loss of electrode voltage which depends only on the temperature and is independent of the dimensions or the normal current for which the furnace is designed; hence
6. The best possible electrode efficiency for any material may be determined from the total voltage of the furnace and this minimum voltage due to the material and the temperature, and is independent of the dimensions.
7. The temperatures indicated by the heat gradient of the combined flow are equal to the sums of those of the individual flows.

The proof of these laws is given in a paper by Hering on "Laws of Electrode Losses in Electric Furnaces"[a] and need not be repeated here.

The fundamental principle involved is the one Hering announced in 1909, namely, that no heat should leave or enter the furnace through the electrode, or, in other words, that the heat generated by the electrical resistance shall raise the temperature of the hot end to that of the furnace; it is shown that under the given conditions this is also the condition of least total loss.

WATTAGE AS A MEASURE OF FLOW OF HEAT.

Before giving the formulas, Hering explained that it simplifies such calculations greatly to represent and measure a flow of heat in terms of the electric unit, the watt, instead of in calories per second. He stated that a watt is just as correct a measure of a flow of current of heat (calories per second) as an ampere is of the flow of electric current (coulombs per second). Heat is a form of energy, and the rate of flow of heat per second is power, hence it is measurable in units of power, such as watts. Since Hering called attention to this point others have endeavored to improve matters by calling this unit "watt-seconds per second," but this cumbersome name is entirely unnecessary and obscures rather than simplifies one's conceptions.

---

[a] Hering, C., Trans. Am. Electrochem. Soc., vol. 16, 1909, p. 265.

It is evident that watts × seconds ÷ seconds = watts. When the heat conductivity of a material is given as 10 watts for an inch cube, it simply means that with a 1° C. difference of temperature between two parallel sides, and perfect heat insulation on the other four, the same amount of energy will flow through as heat, say into water at the cold end, as would enter the water from a coil of resistance wire in which 10 watts were being set free.

For these reasons, in the following discussion, quoted from Hering[a] all flows of heat are represented in watts. Hering recommends that all thermal constants pertaining to electrodes be given in terms of watts instead of calories per second. The conversion factors are: Gram-calories per second × 4.18617 = watts, and watts × 0.238882 = gram-calories per second. The abstract from Hering follows:

FORMULAS.

The value of the symbols used in the following formulas are the same whether inches or centimeters are used, providing they are employed consistently throughout, including all those constants which are based on dimensions, and which of course will be different; those like the electrode voltage or watts per ampere are, of course, the same in both systems. All of the formulas in which the following symbols are used are in terms of actual units and may therefore be used directly in practice.

Let S=cross section in square inches.
L=length in inches (the essential length).
I=current in amperes.
W=watts generated electrically in the electrode.
H=heat flow in watts which would flow if there were no current.
h=heat flow in watts which enters the hot end from the furnace.
X=heat flow in watts leaving the cold end.
T=temperature drop in centigrade degrees between the hot and cold ends.
r=electrical resistivity in ohms, inch cube units.
k=thermal conductivity in watt, inch cube units.
e=electrode voltage in volts.
E=total voltage between the two ends, or the watts per ampere.
s=specific cross section in square inches.
S'=section in square inches per ampere per inch of length (or in square centimeters per ampere per centimeter length if the other quantities are in terms of centimeters).

DETERMINATION OF PROPER SIZE OF ELECTRODES.

The underlying feature is that the electrode shall not chill the furnace nor develop a high temperature point within the walls at which the temperature is greater than in the furnace. Hence the hot-end temperature should be as nearly as practicable equal to that of the furnace.

The current and furnace temperature are always given in the specifications. The material and either the length or the section (but not both) may also be specified, but preferably all three should be left to the designer. The voltage and loss can not be specified, as they are determined by the current, temperature, and material.

The length (that is, the essential length, not including additions to either or both ends for other purposes than to get the energy through the walls) may be determined solely by the thickness of the furnace walls; but as this affects the cross section, some latitude should be left in case the corresponding section is found to be too large or too small to be practicable.

---

[a] Hering, C., loc. cit.

The section in square inches is then determined at once by multiplying the proper temperature value of S' from the table ["constants for calculating electrodes"] by the current in amperes and by the length in inches. Formula: $S=ILS'$. If this is too large or too small to be practicable, the length may be changed and the section may be redetermined. The quotient of the section divided by the length is a constant for any specified conditions (numerically equal to S' from the table multiplied by the current), hence they may both be increased or decreased in the same proportion.

Should this table of values not be available and the specific section be known, formula $S=ILs\sqrt{T}$ should be used for calculating the section. If this is also not known, then use the conductivities in the formula $S=IL\sqrt{r+2kT}$. Great accuracy is not necessary when one is near the correct result, as an error in section near that point produces a relatively much smaller error in the loss.

The loss in the electrode in watts is entirely independent of the section or length adopted, provided only that their quotient is approximately as above. It is calculated in watts by multiplying the corresponding temperature value of E in the table by the current (formula $mX=IE$). If this table is not available, we may use the electrode voltage in the last part of formula $mX=2H=W=I\sqrt{2krT}-Ie\sqrt{T}$. If this is not available either, then use the conductivities in the preceding expression of this formula. This loss is for one electrode and it is the least possible under those conditions.

Constants for calculating electrodes.

Temperature.		E. (Watts per ampere.)				S′. (Square inches per ampere per inch length.)				S′. (Square centimeters per ampere per centimeter length.)			
°C.	°F.	Carbon.	Graphite.	Iron.	Copper.	Carbon.	Graphite.	Iron.	Copper.	Carbon.	Graphite.	Iron.	Copper.
400	752	1.00	0.85	0.145	0.095	0.00165	0.00040	0.000103	0.000016	0.0042	0.00100	0.00026	0.000041
600	1,112	1.38	1.04	.225	.140	.00114	.00031	.000102	.000015	.0029	.00078	.00026	.000037
800	1,472	1.68	1.19	.295	.184	.00090	.00027	.000101	.000014	.0023	.00068	.00025	.000036
1,000	1,832	1.93	1.32	.350	.226	.00076	.00024	.000098	.000014	.0020	.00061	.00025	.000036
1,200	2,192	2.15	1.43	.410	.270	.00069	.00022	.000094	.000014	.0018	.00056	.00024	.000035
1,400	2,552	2.36	1.52	.460	.310	.00062	.00020	.000092	.000014	.0016	.00051	.00023	.000035
1,600	2,912	2.53	1.62	.510	.351	.00057	.00019	.000089	.000014	.0014	.00048	.00023	.000035
1,800	3,272	2.68	1.71	.565	.391	.00053	.00018	.000087	.000014	.0013	.00046	.00022	.000035
2,000	3,632	2.83	1.79	.610	.430	.00049	.00017	.000085	.000014	.0012	.00044	.00021	.000035

When the current for a furnace varies appreciably, the calculations must of course be made for some assumed normal value, remembering that whenever it is less than that the electrode will chill the furnace more or less; and whenever it is greater the electrode will get hotter within the walls and in both cases the total loss will be greater.

In operating a furnace, if the electrode is found to chill the product it is either too short or too large in section. If, on the other hand, it is found to produce excessive temperatures within the walls, it is too long or too small in section. The current density is not a determining factor.

The hotter the outside terminal is allowed to get, the smaller the loss, but the larger the section or shorter the electrode.

When the proportions turn out to be large in section and short in length the relative proportions may be improved by increasing both length and section. On the other hand, if the electrode is abnormally long and small in section (as for instance with iron or copper and small currents), then if the section can not be made smaller, there seems to be nothing left to do except to sacrifice some of the loss by making the electrode shorter and it will then chill the furnace more or less.

The additional lengths of the electrode necessary for the terminals, for feeding, or for the distribution of the current in the inside, must be calculated separately; as they are determined by entirely different laws and conditions; the above refers only to the essential part which is necessary to get the current into and out of the furnace as well as possible. The above length must, therefore, never include the long external part outside the furnace for feeding purposes. Such a part radiates heat to the air, and therefore follows entirely different laws of proportions. A redeeming feature of such a case is that the outside temperature used to determine the proportions of the essential part, may be allowed to be very high, probably limited chiefly by oxidation, thereby reducing the total loss which has been increased by the long external part.

PROPER CONSTRUCTION OF ELECTRODE HOLDERS.

HEAT SOCKETS AND CLAMPS.

When the current is fed into the end of the electrodes, as in some carbide and ferro-alloy furnaces, the connections are applied by means of heat sockets whereby they are frequently attached once for all. The other method is to use clamps which permit the electrode to be passed through them, their clutches being merely pressed tightly against the smooth hard furnace electrode.

The latter is preferred as a means of conducting the current to the electrode, owing to the fact that thus it is possible to place the "electrode holders" immediately on the roof of the furnace and keep them stationary. This arrangement permits the introduction of the current as close as possible to the end of the electrode where it enters the charge, so that less energy is spent in overcoming the resistance of the electrodes themselves than when the current is introduced at the end of the electrode. The connection between the cables and bus bars carrying the current to the furnace, and the electrodes, which, as before stated, serve to carry the current into the furnace, is made by electrode holders. These holders for convenience may be divided into two classes, namely, top holders and side holders.

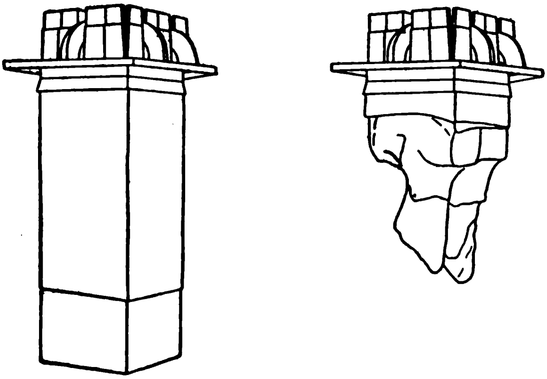


FIGURE 14.—Trollhättan electrode before and after use. Old type of holder.

TOP HOLDERS.

With top holders the current is introduced at the top of the electrode through a holder such as is shown in figure 14. The holder attached to the end of the electrodes is also shown in figure 15; and, as will be noted by reference to the figure, the same contact surface is maintained between the holder and the electrode until the electrode is used up. Top holders are generally used in open-top furnaces, such as the ferrosilicon and carbide furnaces, and in all furnaces in which a frequent raising and lowering of the electrode is necessary. If the electrode as a whole is subjected to erosion from any cause, it is then practically necessary to use a top holder, owing to the fact that the uneven surface produced by the erosion would prevent a quick and effective fitting of the electrode holder to the electrode, especially after the electrode became hot, and the proper contact between the holder and the electrode is, as can be readily understood, of great importance.

SIDE HOLDERS.

Side holders are generally used on closed-top furnaces or on constructions in which the electrode above the holder will not be subjected to sufficient heat to bring about its oxidation and thus cause it to have an irregular surface. Electrodes used with side holders must be of fairly uniform dimensions. For this reason, graphite electrodes are better adapted for use for side holders than are amorphous-carbon electrodes, as they are more easily machined. This is especially true where it is desired to keep the top of the furnace not only closed but tight, as for example in the Swedish and California types of iron reduction furnaces. In these types of furnaces the electrode holder is placed on the roof of the crucible, for in this way the current is conducted into the electrode at a point where it will have the shortest distance to travel before it reaches the point where it does its work, and in this way the electric-energy loss that may be due to the resistance of the electrode is reduced. Then, too, it is to be remembered that the ohmic resistance of carbon decreases with increasing temperature, and as the hottest part of the electrode will be that part that extends down into the furnace, the ohmic resistance of the electrode is reduced to a minimum by getting the holder as near the hot end of the electrode as possible. The side holder permits of the joining of one electrode to the other without the removal of the holder, an arrangement that is, of course, decidedly advantageous.

ESSENTIAL DETAILS OF HOLDERS.

In the construction of electrode holders all current-carrying parts are usually of copper or bronze, the main posts and supports being of steel. A current density of from 19 to 30 amperes per square inch is usually adopted for the current-carrying contact parts, the lower limit being preferred.

As before stated, the surface condition of the electrode is of the reatest importance, so far as the making of a good contact between the holder and the electrode is concerned. If the contact is not a good one the holder becomes hot and may even be ruined. On small furnaces not equipped with water-cooled holders it is especially necessary to have a good contact between the holder and the electrode, and so elastic layers of copper netting, thin iron sheets, or something of the kind, is used to insure a good contact. Efficiency, of course, demands a good contact between the electrode and the holder, even if the holder be water-cooled, for although the water cooling may prevent the holder from becoming excessively hot, the heat developed is at the expense of electrical energy, and is simply carried away by the cooling water without having done useful work. Then, too, a bad contact is likely to cause the electrode itself to become red-hot adjacent to the holder, and thus cause a serious deterioration of the electrode, due to burning; and the excessive heat from the electrode may cause a water-cooled electrode holder to crack or break, and because, as before stated, ohmic resistance decreases with increasing temperature, the flow of current will be greatest through the hot part of the electrode and will cause this hot part to become still hotter.

As illustrating the importance of using the best type of electrode holder possible, the following figures are taken from an article that appeared in "Stahl und Eisen,"[a] a translation of which has been published in Metallurgical and Chemical Engineering.

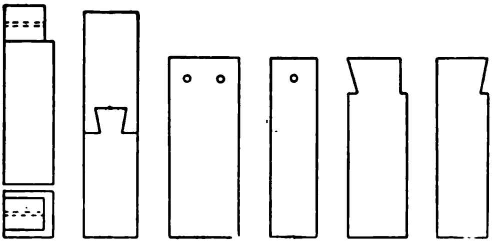


FIGURE 15.—Specially shaped electrodes for electric furnaces.

In a large plant producing 4,000 tons of ferro-alloys per year the cost of maintenance of the holders was marks 6.40 ($1.60) per ton of metal produced, or marks 25,600 ($6,400) per year. By using an improved holder this cost was reduced to marks 1.60 ($0.40) per ton, saving marks 19,200 ($4,800) annually. The consumption of electrodes was also reduced, resulting in an additional saving of marks 12,800 ($3,200). The total saving due to the use of an improved holder was, therefore, marks 32,000 ($8,000), or marks 8 ($2) per ton of product.

SPECIALLY SHAPED ELECTRODES.

Owing to the fact that it is important to effect the proper contact between the electrode holder and the electrode, it was rather common practice to shape the ends of the electrodes to fit the holders, especially where top holders were used, and as good amorphous carbon is generally difficult to machine properly, the particular shape desired was given to the electrode before baking. Some of these special shapes are shown in figure 15.

---

[a] Anon., Die Electrodenfassungen bei Electroöfen: Stahl und Eisen, vol. 33, 1913, pp. 472–478, 555–561. Translated by Kennelly, A. E., Electrode-holder construction for electric furnaces: Met. and Chem. Eng., vol. 11, June, 1913, p. 321.

TYPES OF TOP HOLDERS.

The subject of electrode holders has been discussed in "Stahl und Eisen,"[a] and a translation of the article has been published in Metallurgical and Chemical Engineering.[b] The following lengthy quotation from this translation is given here:

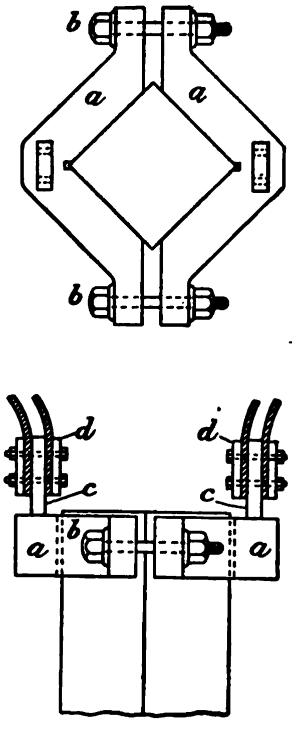


FIGURE 16.—Holder formerly used with carbide furnaces.

> In carbide plants the connection shown in figure 16 was formerly often used, consisting of two solid V-shaped cast-iron clamps *a*, tightened by bolts *b*, and connected to the cables by means of necks *c* and pressure plates *d*. This solid electrode holder never proved satisfactory. When the electrode became short the holder as well as the electrode became hot and the cast-iron pieces often melted. Later on, a cooling device was combined with this construction, as shown in figures 17 and 18.
>
> Figure 19 shows a connection that has proved satisfactory in a carbide furnace. The head of the electrode is dovetailed and clamped between two cast-iron plates *b* by means of two weights *a*. The whole apparatus is supported by an iron structure which itself hangs on an electrically insulated hook. Copper plates *d*, *e*, and *f* serve to make contact at *h* with the flexible laminated ribbons *g*, carrying the current. The mechanical suspension is independent of the electric connection, and the weight of the electrode tends to tighten the contact between copper plates and electrode head. An electrode equipped with this holder can be put into service very quickly by hooking into the chain of the windlass and making contact at *h*.
>
> The holder shown in figure 20 has been successful in the manufacture of ferro-alloys. The electrode consists of four carbon blocks embedded in a tamped carbon mixture. Two opposite surfaces of the same block have dovetailed recesses in order to clamp the copper plates *a* by means of the screw bolts *b* and the plates *c*. This holder is simply connected to the plates *d* of the current load *e*. The plates *a* preferably consist of copper, the plates *c* of steel casting, the pressure screws of iron with square threads, and the plates *d* of bronze or of cast iron containing manganese.
>
> If the surface of the dovetails is not smooth enough to secure a good contact, the heating at the contact will be avoided by putting a cushion of very fine strands of a copper cable between the carbon and the copper plate. Under the pressure of the screws this cushion of about 0.5 cm. ($\frac{3}{16}$ inch) thickness is pressed into the rough spots of the carbon and secures the passage of the electric current under favorable conditions.
>
> When the electrode butts are to be utilized down to a length of 50 cm. (20 inches) it becomes necessary to cool the parts artificially to prevent the holder from being destroyed by the heat of the furnace. Figure 21 shows the copper plates of the current lead being wedged to the carbon by means of water-cooled channels, *a*, open at the top. This design has given good results, especially in furnaces with an open hearth.

---

[a] Anon., Die Electrodenfassungen bei Electroöfen: Stahl und Eisen, vol. 33, 1913, pp. 472–478, 555–561.
[b] Issue of June, 1913, pp. 321–324.

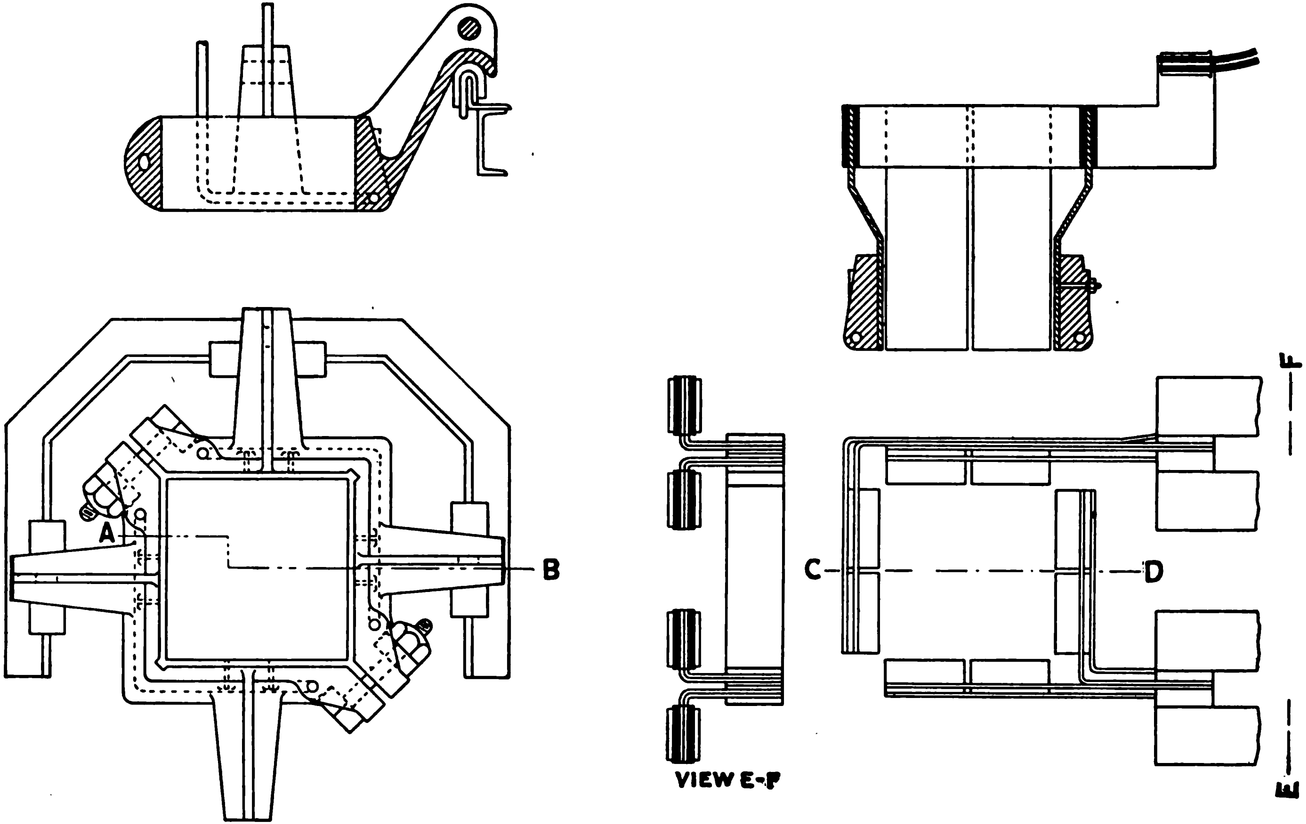


FIGURE 17.—Electrode holder with cooling device.

The holder shown in figure 22 is good for cylindrical electrodes. The flexible leads are fastened to a bronze piece, *a*, of special form. This piece is fastened to the carbon by an electrically insulated ring and has a contact surface machined on the lathe. The holder itself is a box, *c*, surrounding the head of the electrode and pressed to the piece *a* by the screws *b*. After loosening the screws *b*, the pieces *a* and *c* can be taken apart by a quarter turn. The piece *c*, which is protected by the iron sheet *d*, is put on top of the electrode, and bronze, *e*, is poured into the free space between the box and the carbon and on top of the electrode.

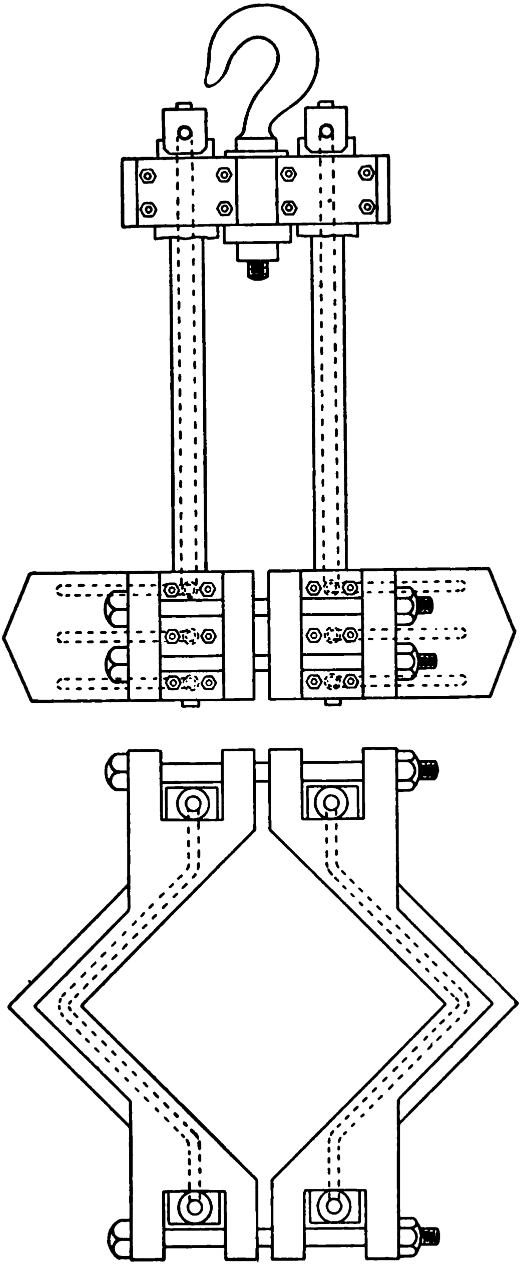


FIGURE 18.—Electrode holder with another type of cooling device.

The weight of the electrode produces an excellent contact between the bronze and the walls of *c*. The holder is cooled with water which enters through *f*, and drops through the central overflow pipe onto the top of the electrode; the admission of water is regulated to make up for evaporation.

Figure 23 shows a holder cooled by water under pressure. The ring-shaped piece *a* is hollow in the center, the water circulating through *b*. Copper sheets, *c*, serving both as mechanical suspension of the electrode and as current leads, are pressed against the electrodes with cast-iron or bronze wedges, *d*. The wedges have regulating screws, and piece *a* is held by four pressure screws.

While an intimate contact is hard to make between a carbon electrode and the cable, it is easily obtainable between the cable and a metallic electrode by screwing the pole shoe at the end of the cable to the electrode. The contact surfaces of the pole shoe and of the electrode can be ground into each other, which warrants a good contact on the entire surface. As it is hardly ever possible to get the surface of a nonmetallic electrode perfectly plane there will always be a certain contact resistance and evolution of heat and it may be necessary to remove this obnoxious heat of the contacts by special contact-cooling devices.

The Westdeutsche Thomas Phosphatwerke have a German patent (No. 207,361) for the construction shown in figure 24. The square-shaped electrodes *a* have a recess on top, and a copper cap *c* is dumped over this head. In order to make good contact where the surfaces do not touch each other, the cap is filled with liquid aluminum or another metal of high melting point. and while the aluminum (or other metal) is still liquid a red-hot wrought-iron ring *e* is shrunk around the copper cap. By the simultaneous gradual cooling of the aluminum and the iron ring a very close contact is produced between the copper cap, the aluminum layer, and the top of the electrode.

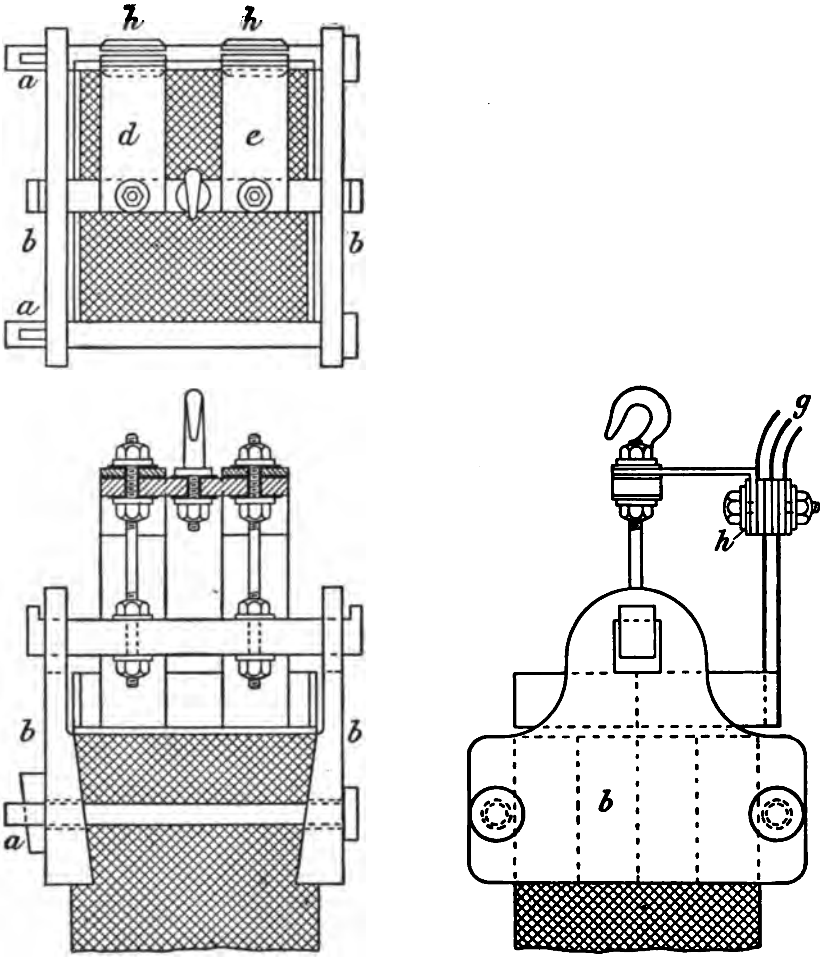


FIGURE 19.—Detailed views of electrode holder satisfactorily used in carbide furnaces.

Contact resistances can not show up any more. The pole shoe *f*, the screws *g*, the hoops *l*, and the cable ends can be seen from the figure. As no soldering is required in this design, an important source of trouble is eliminated.

With the patterns of holders described so far, the remaining butt of the electrode, which is about 50 cm. (20 inches) long in furnaces with an open hearth, is not used.

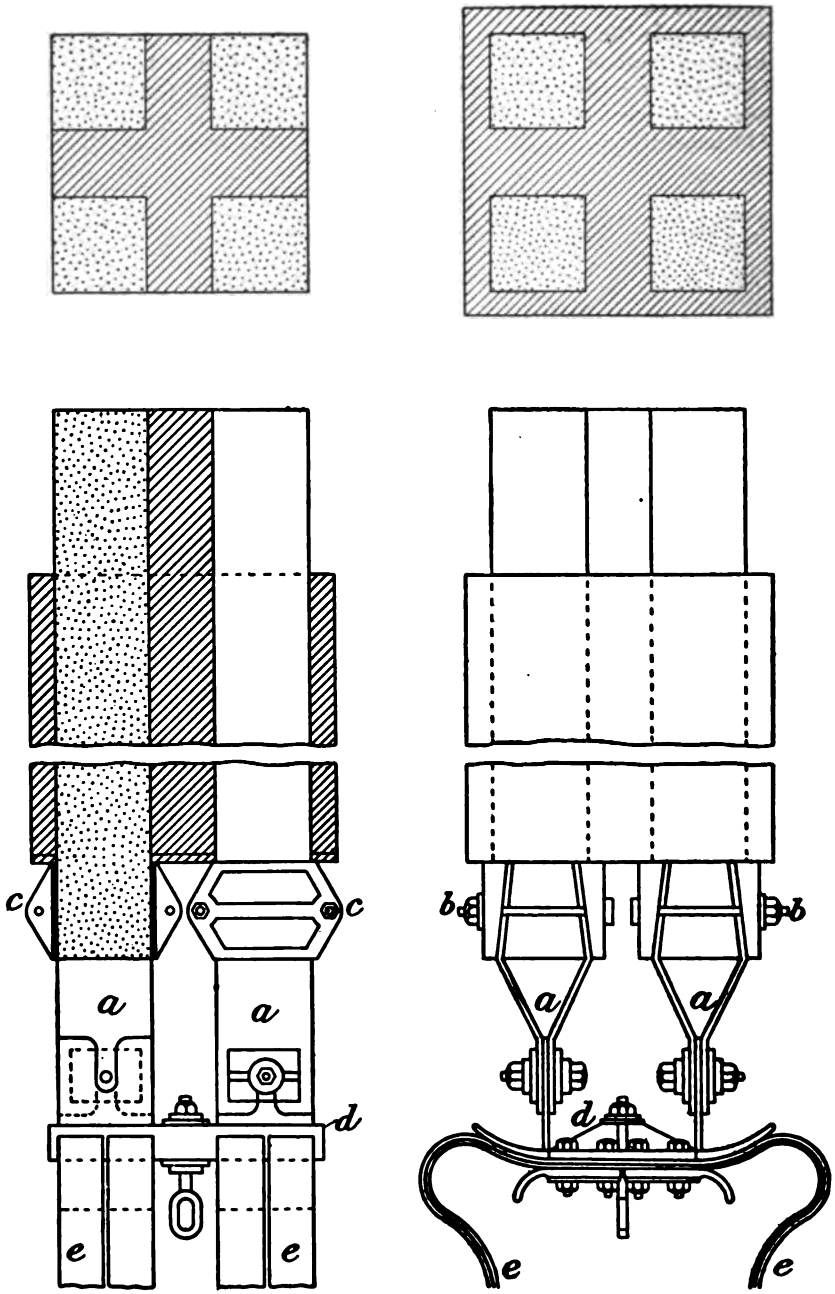


FIGURE 20.—Another type of electrode holder satisfactorily used in carbide furnaces.

In furnaces with arches, as for instance, in electric steel furnaces, the discard is larger, leaving a butt of about 90 cm. (36 inches), which means that only about one-half of the electrode can be used.

MOVABLE SIDE HOLDERS.

In order to utilize completely the electrode material, movable holders are employed which allow the electrodes to slide through. The electrode is not held on one end, but somewhere between its two ends connection is made to the cable; when a piece of electrode is used up, another piece of carbon is added to the previous piece, and the holder raised accordingly.

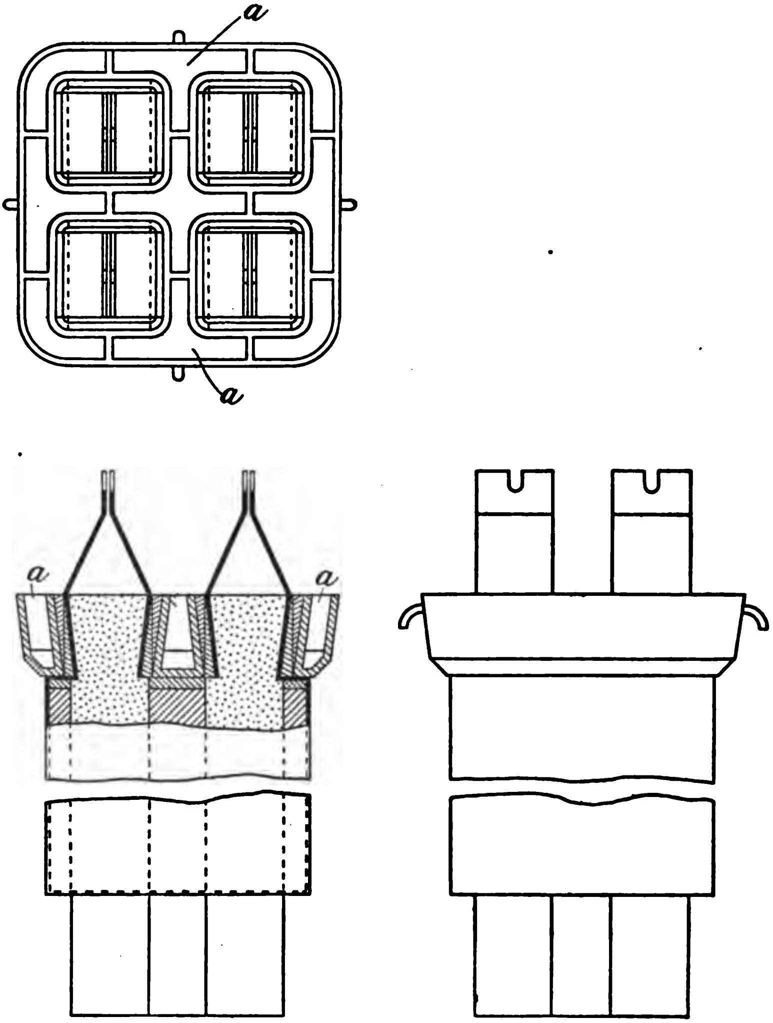


FIGURE 21.—Water-cooled electrode holder.

Figure 25 represents this type of connection in a design proposed by Louis. The electrode is held between two hollow pieces of metal, *a*, which form a pair of tongs.

The tongs are pressed against the electrodes by the screw *b*. When the lower part of the electrode is consumed, it can be fed downward for the desired length. The cable is fastened at *c*; the best way of cooling the pieces *a* and the contact is by means of water under pressure.

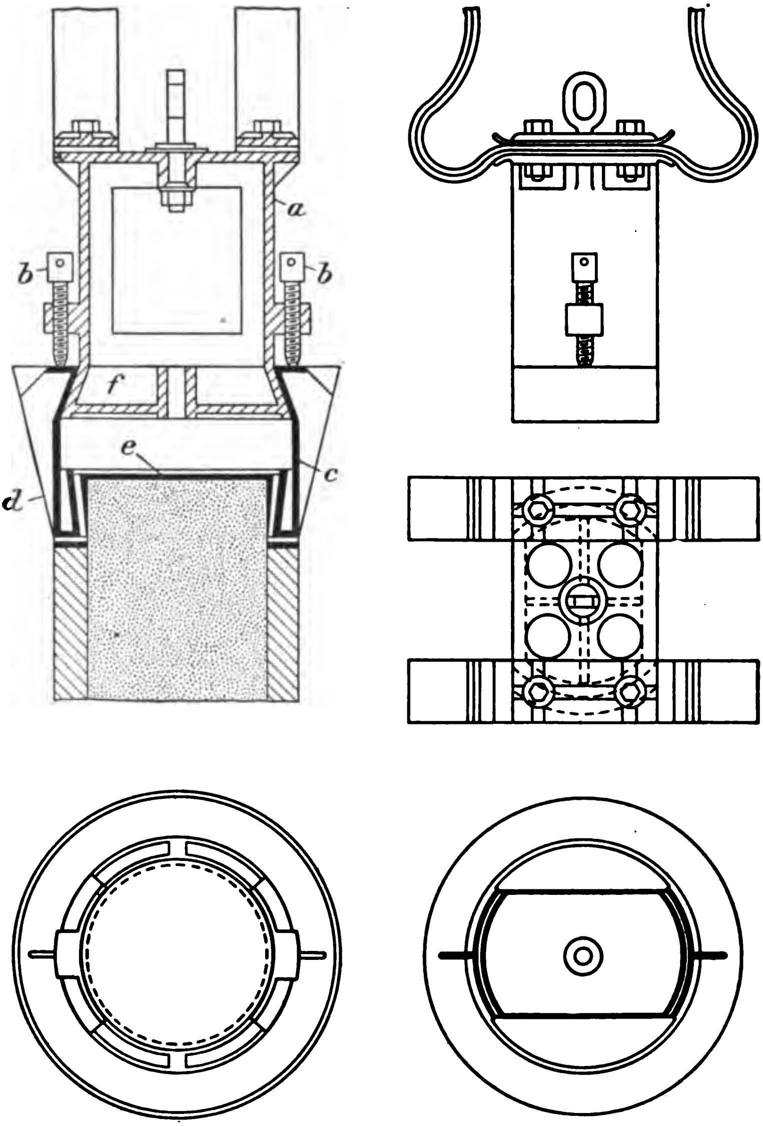


Figure 22.—Holder for round electrode.

Figure 26 shows another tongs design for a combined electrode of several blocks. The carbon blocks are pressed by steel levers by means of the screws *a* against the central piece of bronze, which serves as suspension and current lead.

Figure 27 shows a similar design in which adjustable wedges are employed which are water cooled.

The holders of most electric steel furnaces are built for complete consumption of the electrode material and have been repeatedly shown to our readers.

In the Héroult furnace each electrode is held by a bracket from a vertical rack, which is moved up and down by gear and pinion. Each carbon is surrounded by a band of metal, pieces of copper being inserted, which carry the current from the cables.

Figures 28 and 29 show various constructions used by the Aktisbolaget Elektrometall Ludwika, and by Nathusius.

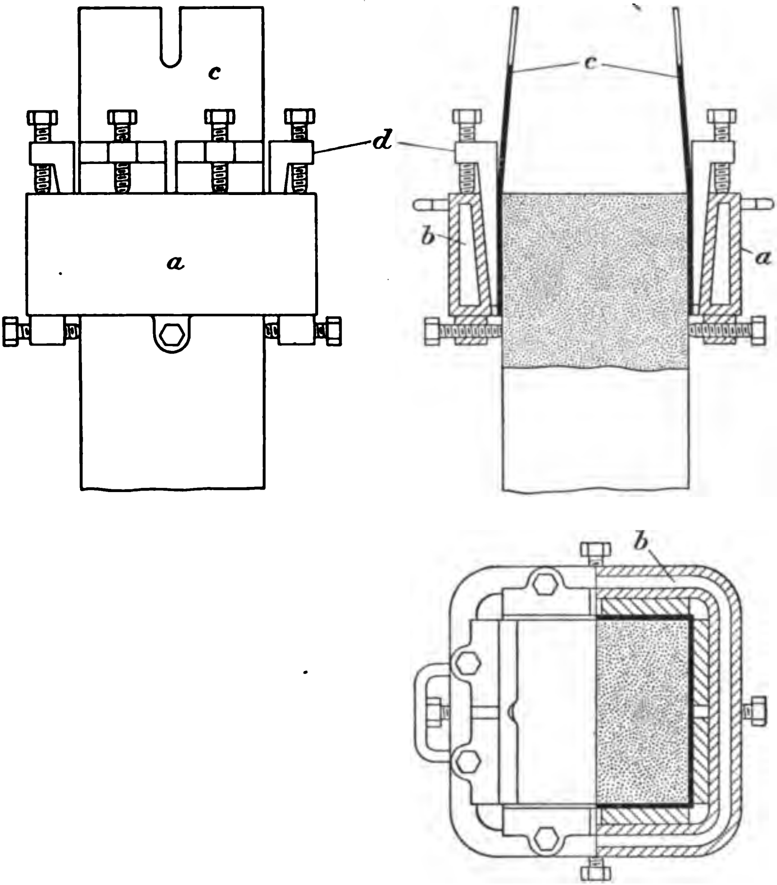


FIGURE 23.—Electrode holder cooled with water under pressure.

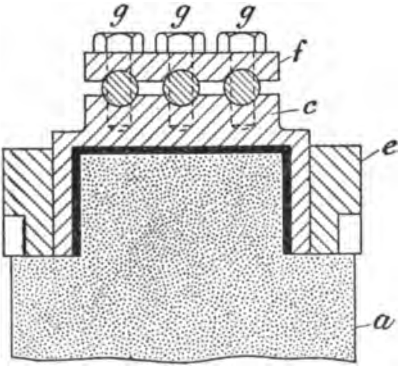
METALLIC CONDUCTORS IN ELECTRODE HEADS.

Keller's method of inserting the metallic conductor into the head of the electrode gives satisfactory results. This method has been known for some time. With small electrodes the connection to the current leads is obtained by means of metallic plates between the conductor and the carbon. But too close a tightening of the bolts often causes the electrode to crack whereas otherwise the contact may be poor.

Figure 30 shows an electrode connection often used for the manufacture of aluminum. The end of a flat piece of iron is upset in the shape of a fishtail and then molded into the electrode. Plants who manufacture their own electrodes insert this connector before baking, whereas those who buy them baked fasten the metal with a graphite mortar or by pouring liquid bronze into the hole.

Figure 31 shows a connection made by a screw bolt. A thread is made in the end of the electrode, and an iron rod, threaded at one end, is fastened in the same. A mantle of bronze or aluminum bronze forms contact at both ends and secures the passage of current. Four or six of these electrodes are sometimes combined in aluminum furnaces, as shown in figure 32.

A connection of Dr. Lessing, of Nuremberg (German patent 211,273), is shown in figure 33. It consists of a piece of iron molded with the electrode which has square-shaped threads of such an angle that the distance *b* between the threads is considerably larger than their thickness *a*. This bolt can be removed from the carbon before baking without destroying the threads in the latter. The iron piece *d* connects with the threaded bolt *c*. By screwing the bolt into the carbon and securing it by a counternut, *e*, an excellent contact is obtained.



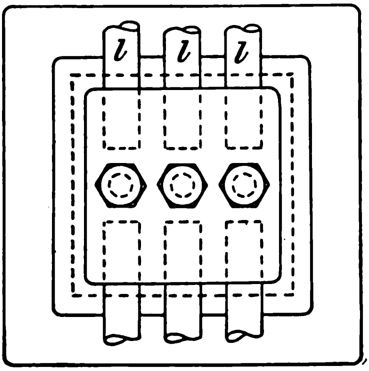


FIGURE 24.—Electrode holder used in Germany.

Keller allows the metallic conductor a certain play, the lower end being tapered thicker into the hollow top of the carbon (German patent 218054; fig. 34). Liquid metal, copper or pig iron, is then poured into the space left in between. This produces a mechanically and electrically reliable contact. No jaws, wedges, or screws are required to make or improve the contact. The interior of the metallic conductor is intensely water-cooled in order to utilize as much length of the electrode as possible. The metal has to be poured carefully into the open gap between conductor and carbon. The cavity in the electrode is first heated by a piece of red-hot iron, the preheated current conductor is then introduced and kept about 5 mm. (0.2 inch) distant from the bottom of the cavity by a small, hard body. Very hot bronze or cast iron is then poured in.

Although the metal shrinks a little, it makes an intimate contact. The effect of shrinkage can be entirely overcome by casting about 30 grams of tin around the contact metal after it has cooled. If the contact should not be perfect, it heats up when the electrode is put to use, the tin melts and flows into the interstices and makes a perfect contact. The costs of this method are said to be low. The contact metal and the tin can be recovered after the electrode has been consumed.

This type of connection is mechanically strong, and its electrical resistance is low. As the cooling effect reaches clear down into the bottom of the cavity in the electrode, the contact will not soften, even when it is heated by the proximity of the arc. The electrode can, therefore, be introduced through the roof of the furnace and be used up to an extremely small rest piece. As no part of the metallic conductor is wider than the electrode, it can pass through the same opening which fits closely around the carbon and can be packed in firebrick up to the diameter of the electrode. This method is satisfactory for single electrodes, as well as for bundles of them.

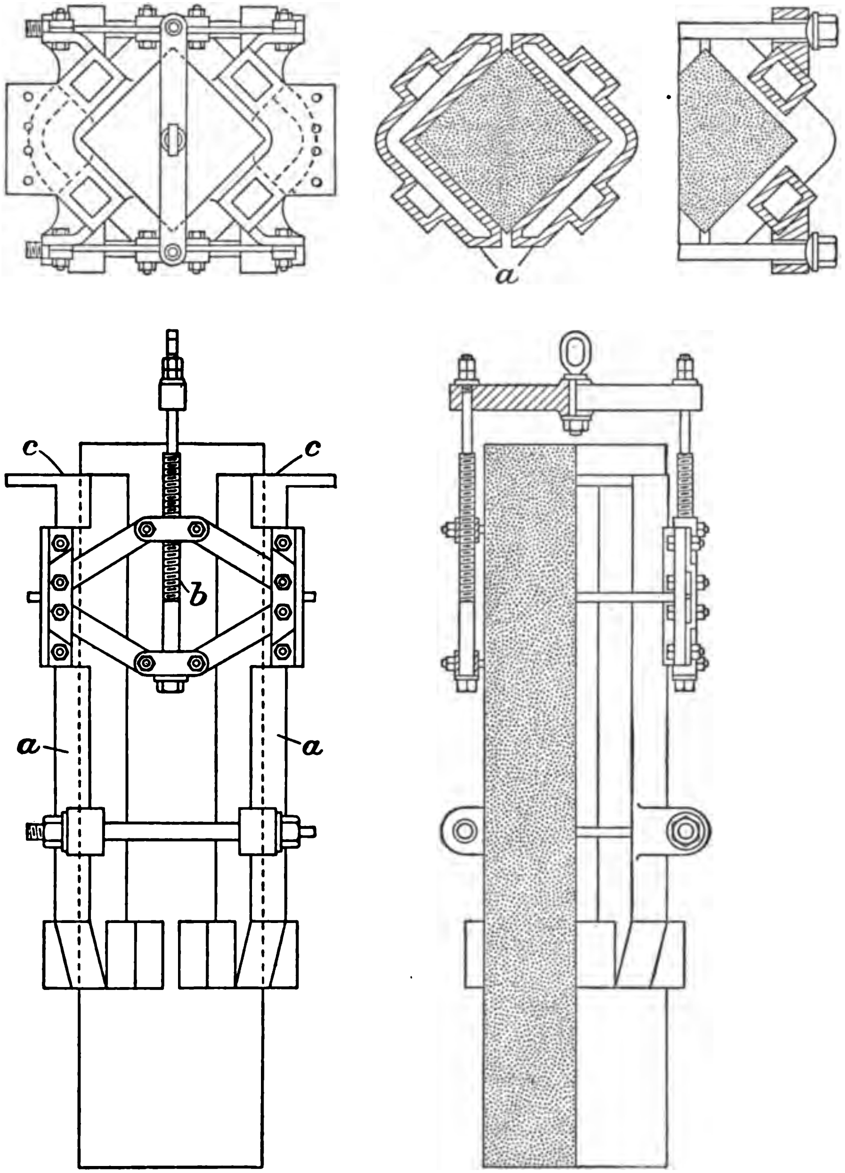


FIGURE 25.—Electrode holder with movable contact.

The advantages of Keller's connection are:

1. It avoids all intermediary contacts between the current cable and the carbon.
2. It avoids all parts extending beyond the area of the electrode, and has no brackets, screw bolts, wedges, etc., which are liable to deteriorate and cause a high maintenance cost.

3. It requires no finishing of the electrode surfaces or of the metallic conductor. There is even a certain advantage in leaving the walls of the cavity roughly finished, as it improves the contact surfaces and the mechanical strength of the joint.
4. The electrical contact is perfect, as the liquid metal fills all the free spaces.
5. The mechanical connection is strong and fool-proof, even when the carbon is almost used up.
6. The cost of maintenance is low.
7. The electrode can be used down to below 25 mm. (less than 1 inch) length, which dispenses with the cumbersome joining of electrodes.

A practical elastic connection between the electrode and the current leads is used by Keller with the above-mentioned electrodes (German patent 194897). The successive up-and-down movement of the electrodes requires flexible leads between the conductor and the carbons. Sometimes an elastic cable of sufficient length serves this purpose. This, however, is subject to considerable wear and tear, takes much space, and is cumbersome for melting furnaces with vertical electrodes, especially so when they lead the current in and out, so that there is the danger of short circuit.

Keller avoids these difficulties by using thin and very flexible leaf springs of copper, for example, 0.5 mm. (20 mils) thick, bundled into two symmetrically arranged bundles and held together at several points by rings. Each side of the electric holder has a guiding rod, which causes the leaf springs to be compressed or opened in vertical direction when the electrodes move down and up. The shape of the leaves is determined by the distance of the rings, which make knots when the springs are deflected or stretched.

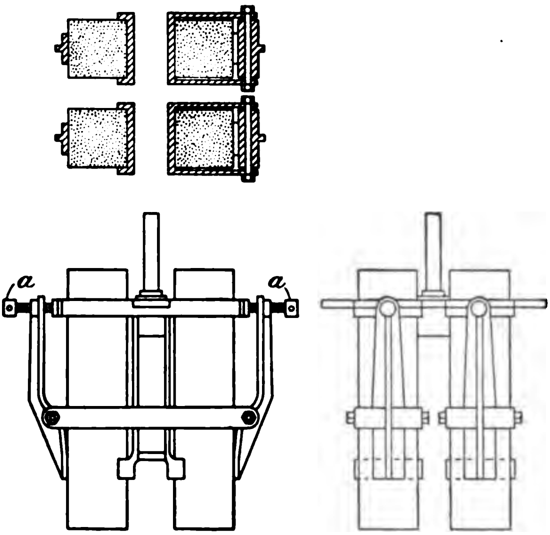


FIGURE 26.—Holder for a block electrode.

If the lengths of the single-leaf springs are somewhat different from each other, the elasticity of each spring is used with best efficiency. There is no danger of a short circuit, and the elastic connection is not exposed to the flames of the furnace. This construction has given excellent service, and is used in electric furnaces of various types and employed for a variety of purposes.

ELECTRODE DIMENSIONS AND ELECTRODE BUNDLES.

The best cross-section of electrodes is one of the most important questions for the consumer. Above all, it is determined by the current density of the electrode. Experience is so far the only guide. A number of important papers on this subject have been published or reviewed in Metallurgical and Chemical Engineering. No general formula which would be valid for all cases has yet been found for the calcula-on of this section. In general, a good electrical and a poor thermal conductivity of n electrode are desirable to reduce the voltage drop and development of heat by the joulean effect, and so prevent any appreciable loss of heat through the electrodes. Much systematic work remains to be done to find the best conditions for improving the heat balance of furnaces in special cases. In view of the fact that the thermal efficiency of the electric arc furnace is 50 per cent or more, these energy losses through the electrodes are of minor importance.[a]

The current density of electrodes depends on the sectional area. It has been proven that round electrodes of from 70 to 100 mm. (2.8 to 4 inches) diameter, as used, for instance, in the Stassano furnace, can carry 20 to 25 amperes per square centimeter (129 to 161 amperes per square inch).[b]

Larger sections are used in the electric steel furnaces of Héroult, Girod, Keller, etc. They can not carry any such current density. Up to a section of 400 by 400 mm. (16 by 16 inches) 5 amperes per square centimeter (32 amperes per square inch) are allowed with a temporary overload of 6 to 7.5 amperes per square centimeter (39 to 48 amperes per square inch).

The large differences in the current-carrying capacity of electrodes of different section are partly due to the thermal and electrical conditions mentioned above. Most of the commercial electrodes are made in presses. The capacity of the press is limited by its dimensions and design, and it seems likely that the smaller sections of electrodes produced under a higher pressure have a denser structure. From this it would seem that the current-carrying capacity of the electrode is determined by the pressing capacity of the machines.

The area of surface exposed to the cooling effect and the resistance of the electrode play, no doubt, an important part in these considerations.

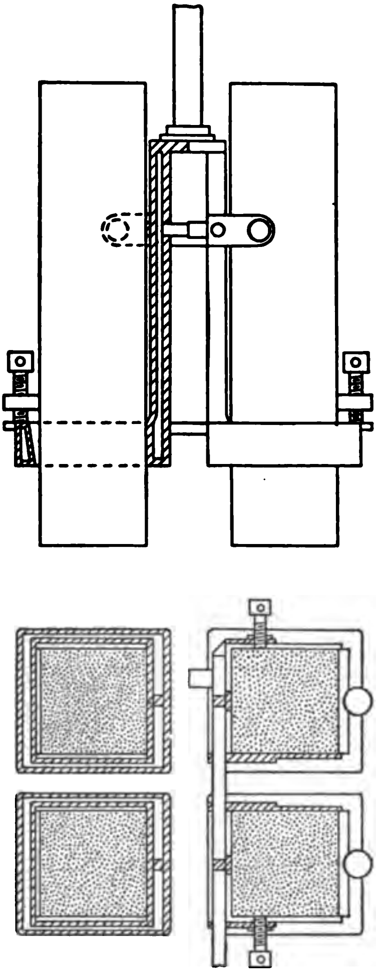


FIGURE 27.—Modification of holder for block electrode.

It is noteworthy, however, how small the differences in the physical constants of small and large electrodes really are. For the identical carbon mixture we find the following values:

Size of electrode.	Specific resistance.	Specific gravity.
80 mm. (3⅛ inches) round.	48 to 50 ohms.	1.55.
300 by 300 mm. (11¾ by 11¾ inches) square.	65 to 68 ohms.	1.50 to 1.52.

---

[a] The reviewer of this article states that he differs on this point. The authors of this bulletin also differ with the statement above made.

[b] The reviewer states that graphite electrodes are used in these furnaces, and account for the remarkable differences from the figures given immediately after for the electric steel furnaces of Héroult, Girod, Keller, etc.

The consumer of electrodes is anxious to reduce the voltage drop by increasing the section of the electrode. The size of section is limited by the design of the furnace and by the facilities of the electrode manufacturer. Recently much progress has been made so that square electrodes of 550 by 550 mm. (21.6 by 21.6 inches) section and round ones of 625 mm. (25 inches) diameter can now be bought from the leading factories.

These large sections naturally involve some disadvantages. The current-carrying capacity is reduced, the mechanical strength decreases with increasing section, and the weight of a single electrode reaches a considerable figure. In case of a broken electrode very heavy pieces might have to be removed from a steel bath and an entire heat might be lost by carburization or by cooling off.

The carbide industry, in which large amounts of energy had to be handled at an early date had previously chosen a different way to overcome the above difficulties. Six or eight or other numbers of smaller electrodes were combined into one package or bundle and lowered by means of cranes into the furnace. The size of the individual electrode is often chosen as 250 by 350 mm. (10 by 14 inches). The electrode packages, as illustrated in figures 19, 20, and 45, leave an unused butt.

The amount of these butts is kept at a minimum by the use of proper water-cooled holders, and whatever remains is used in the carbide furnaces for patching the hearth.

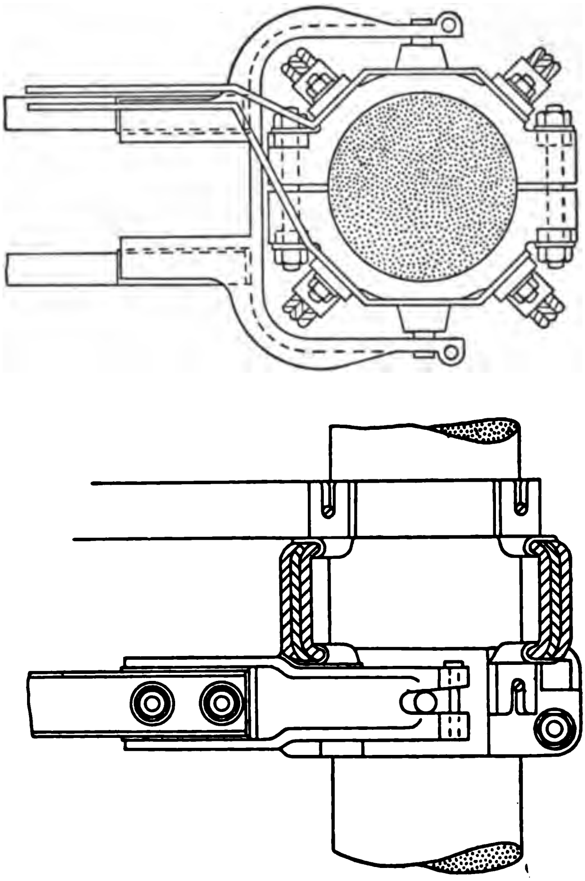


FIGURE 28.—Electrode holder used by the Aktisbolaget Elektrometall Ludwika.

The electric pig-iron furnace in Dommarfvet used three electrodes, each composed of two individual carbons; the over-all section was 660 by 330 mm. (26 by 13 inches). In Trollhättan [a] each electrode consists of four pieces of 2 mm. (0.79 inch) length and 330 by 330 mm. (13 by 13 inches) section, giving a section of 660 by 660 mm. (26 by 26 inches) over all.

---

[a] This practice is no longer followed at Trollhättan, round electrodes being used.

The combining of smaller pieces offers the additional advantage that the individual electrode has a higher current-carrying capacity and that considerable losses of energy are avoided.

Attempts have been made to increase the conductivity of the electrode, for the sake of decreasing the section, by providing a metallic core. Héroult suggested as early as 1892, in United States Patent 473117, to bore holes through the electrodes and fill these with aluminum alloys or silicon alloys.

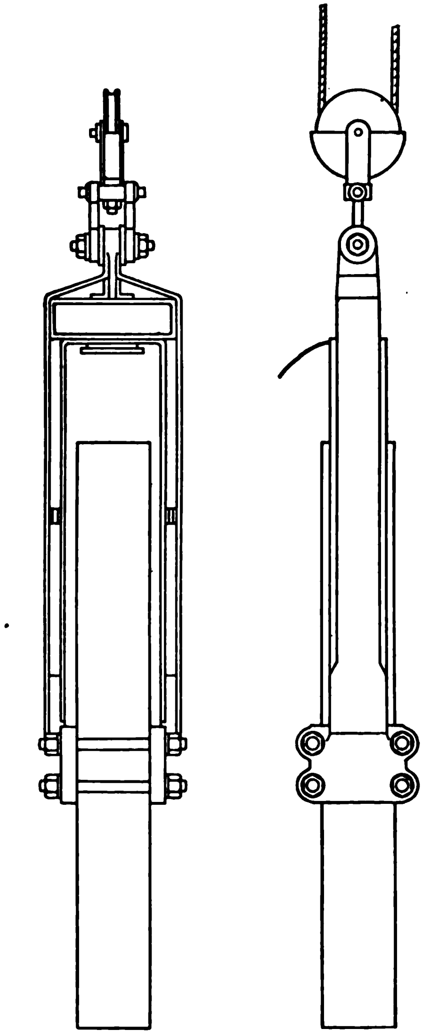


FIGURE 29.—Electrode holder used by Nathusius.

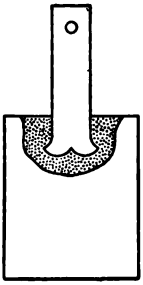


FIGURE 30.—Electrode with iron connection in top.

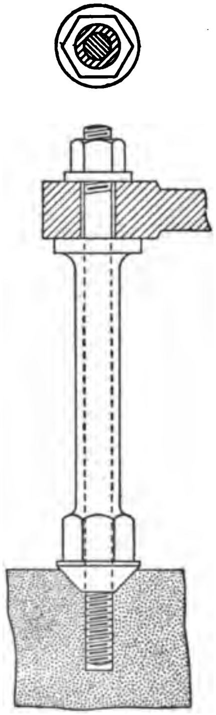


FIGURE 31.—Screw-bolt electrode connection.

The Planiawerke in Rutibor, Germany, improve the conductivity and mechanical strength by metal fillets introduced before or after the baking of the electrodes. (Norwegian Patent 21366, 1910.) The melting or volatilization point of the metal should be below the reaction temperature of the furnace. Measurements show that the resistance of such electrodes "reinforced" by a metallic core can be reduced to at least one-half of the original with a comparatively small cross section of the core.

The process is particularly intended for use with rather long continuously fed electrodes. Certain alloys can be introduced into the steel by using same as the core.

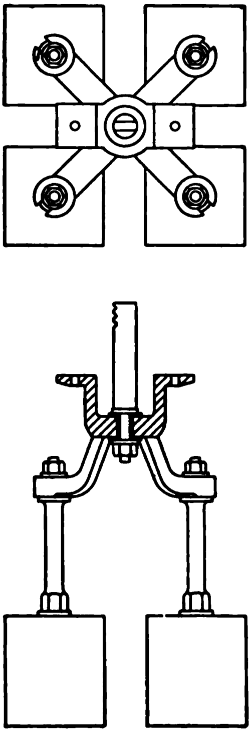


Figure 32.—Combination of four screw-bolt electrodes.

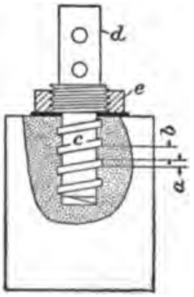


Figure 33.—Electrode connection used by Lessing.

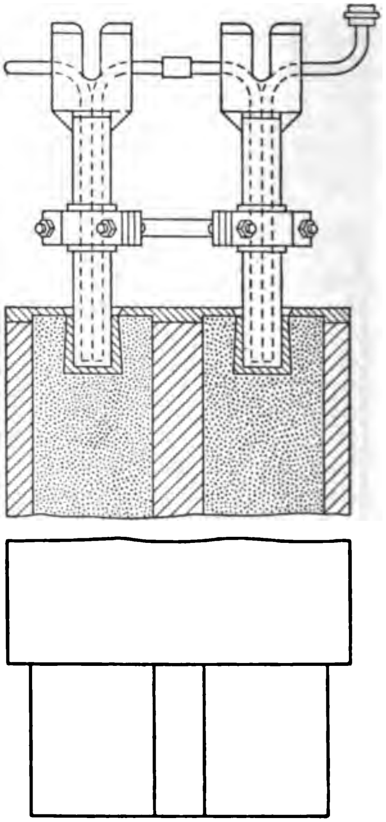


Figure 34.—Electrode connection used by Keller.

According to Perkins a tube of the carbon or iron can be filled with lime, iron oxide, or other slag-forming materials and thus deliver the very liquid refining slag at the hottest point of the bath.

Figure 35 shows the form of electrode holder used in the Stassano nace.

JOINING OF ELECTRODES.

Owing to the fact that the item "cost of electrodes per ton of metal produced" or "per pound of metal produced" is excessive if the electrode is rejected as soon as it becomes too short to permit further use, as is the used electrode shown in figure 15, numerous methods have been devised for joining electrodes together so as to permit continuous feeding. This is generally done in one of three ways (fig. 36), namely, (1) by means of a nipple molded with a screw thread, and made out of the same material as the electrode; (2) by means of a cylindrical threaded plug, which is screwed equal distances into the ends of the two electrodes to be joined; or (3) by means of a threaded male and female joint.

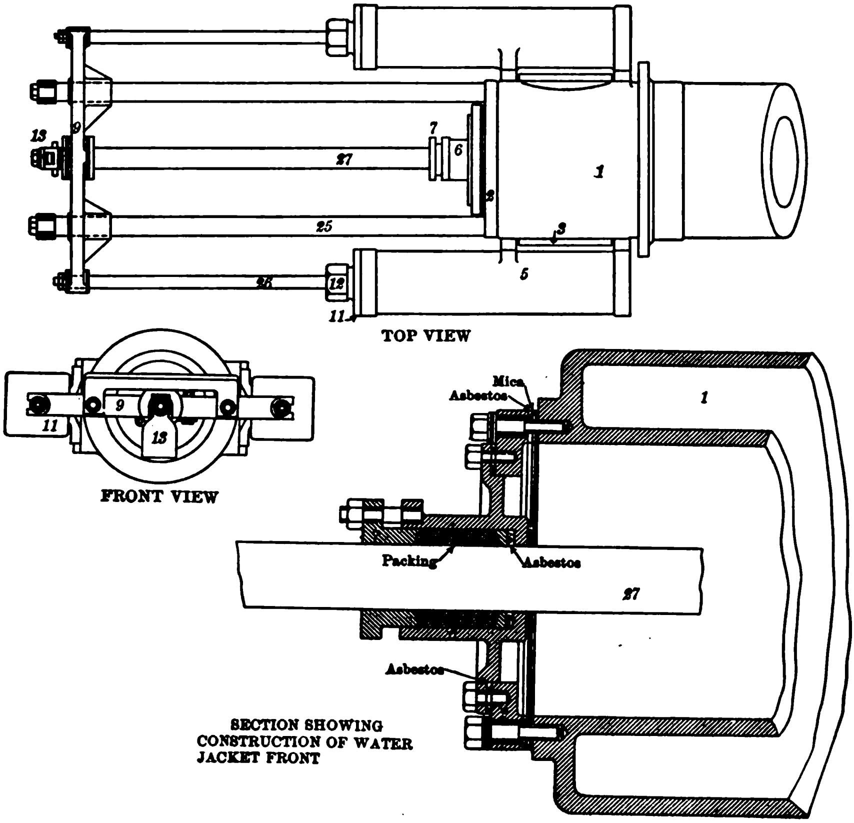


FIGURE 35.—Electrode holder used in Stassano furnace.

Fitzgerald[a] states that as a result of numerous experiments it was found that the joint best suited to the average furnace needs is made by using a threaded plug, in the manner stated second above and that a shallow rounded thread proves better than a pointed one or even a truncated one, as there is less tendency to breakage during assembling.

---

[a] Fitzgerald, F. A. G., Hinkley, A. T., Experiments with furnace electrodes: Trans. Am. Electrochem. Soc., vol. 23, 1913, p. 333.

ELECTRICAL LOSS AT JOINTS.

A certain loss of voltage takes place at these joints. "This loss has been found to be 2 to 2.5 volts for square electrodes of 280 to 330 millimeters (11 to 12 inches) side length with a current density of 5 amperes per square centimeter (32.25 amperes per square inch). This would mean a drop of 4 to 5 volts for an electric steel furnace with two arcs in series, or a loss of 16 to 20 kilowatts for a 500-kilowatt load, which represents 3.5 to 4 per cent of the total energy."[a] Such being the case, the saving in electrode material and time by joining electrodes together has to be balanced against this loss.

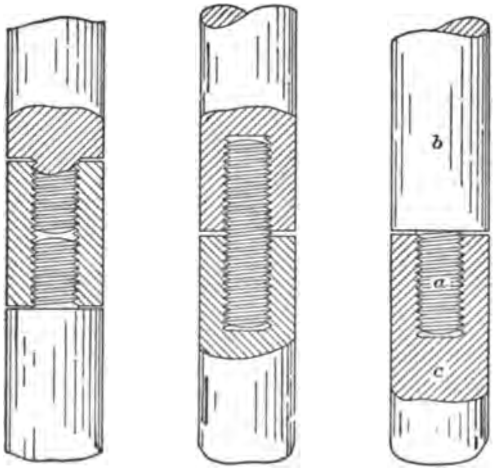


FIGURE 36.—Three types of electrode joints.

The reason for this loss of voltage at the joints is due to the fact that if the electrode be joined by means of a threaded joint, as shown in figure 36, there is liable to be good contact only between the threaded parts (*a* and *c*) of the electrodes, whereas the surfaces of the ends of the electrodes do not come in contact with each other at all. On this account, the current is all crowded on to that part of the electrode carrying the male thread *a*, a condition that not only gives rise to the loss above mentioned, but causes the electrode to become so overheated at this spot as to cause it to go to pieces. It has been suggested that with electrodes of amorphous carbon this difficulty might be overcome by joining the electrodes together by a graphite dowel, as also shown in figure 36. As the conductivity of graphite is about four times that of amorphous carbon, the graphite dowel could be made of such a size as to readily carry the full amount of current carried by the carbon electrode, and in this way the loss above referred to would be reduced to a minimum.

---

[a] Anon., Die Elektrodenfassungen bei Elektroöfen: Stahl und Eisen: vol. 33, 1913, p. 472. Translated by Kennelly, A. E., Met. and Chem. Eng., vol. 11, June, 1913, p. 323.

In this connection the article[a] mentioned above may well be quoted, as follows:

> It has also been proposed to make these connecting studs from metal. This, however, would defeat the special purpose of these studs. They would melt and volatilize and not fill their purpose, since their object is to use the last piece of the electrode. This latter aim is completely reached by a joint containing small particles of metal embedded in carbon.
>
> The disadvantages of this method are as follows:
>
> 1. The manufacture of the accurate inner thread and nipples and other shapes increases the cost of the electrode construction.
> 2. The contact resistance causes losses of energy.
> 3. The joint is apt to loosen and to increase these losses or the end of the electrode in the furnace may drop off, causing short circuits or other troubles; too tight a joint might result in a breaking of the two carbon pieces. (Borchers, Elektrische Oefen, 2d ed., p. 143.)
>
> These difficulties are unknown in the use of electrodes which are not joined together; it is mainly a matter of calculation whether to join electrodes or not, and the cost of power, the cost of electrodes, and their length will decide which of the two methods should be used in any case. In cases in which the furnace and the holder allow the use of the electrode down to but a small stump it will be in many cases more advisable not to join the electrodes.

The rate at which electrodes are consumed depends largely upon (1) whether they are exposed to the action of an oxidizing atmosphere, and (2) the nature of the charge, or of the material that is being heated in the furnace.

COST OF ELECTRIC POWER.

Naturally, all other conditions being favorable, the use of the electric furnace in the smelting of ore and the production of metals and ferro-alloys will depend largely upon the cost of electric power.

HYDROELECTRIC POWER.

Ordinarily one thinks of electricity as being most easily developed by water power. In a way this is true, but as to whether power can be as easily and cheaply produced in this manner as by steam or gas will of course depend on the initial cost of installation, which, in turn, depends, among other things, upon the following:

1. The mean average flow of water for 12 months.
2. Whether expensive reservoirs have to be constructed.
3. Whether these reservoirs are situated a long distance from the site of the power plant, thus necessitating the construction of long ditches, flumes, tunnels, or pipe lines.
4. Whether expensive dams have to be constructed.

In all the forms of water power that are available, either one or all of the above-mentioned prerequisites have to be given serious consideration, although the cost of installation may be as low as $48 per kilowatt or as high as $400. As shown in the accompanying table (p. 70), the cost of hydroelectric power to the consumer may vary from $5 to $60 per kilowatt-year, depending largely on local conditions.

---

[a] Anon., Die Elektrodenfassungen bei Elektroöfen: Stahl und Eisen: vol. 33, 1913, p. 472. Translated by Kennelly, A. E., Met. and Chem. Eng., vol. 11, 1913, p. 324.

POWER PRODUCED BY GAS ENGINES AND STEAM TURBINES.

Of late years a great deal has been written regarding the production of cheap electric power by generators driven by gas engines. Although power can be produced cheaply by such generators when waste gases from a blast furnace are utilized, yet if coal be burned in gas producers to produce the necessary gas, even though the coal used be of inferior quality, and by-products are recovered, the cost of electric power made in this way is rather likely to be more than what is generally supposed to be the cost when gas engines are used for driving the generators.

With the introduction of steam turbines of high efficiency the cost of electric power has been much reduced during recent years. From the figures in the two tables following, which were kindly supplied to the Bureau of Mines by a reliable engineering firm, it seems that with large units the cost per kilowatt-hour is less for a turbine-driven generator plant than for a gas-engine plant.

Plants driven by producer gas from bituminous coal and turbine plants of 2,000 kilowatts, 4,000 kilowatts, 6,000 kilowatts, 8,000 kilowatts, and 10,000 kilowatts normal capacity are considered in these tables. In each plant all units are of uniform size. The data are given on the basis of a 75 per cent load factor. The maximum size of the gas engines covered is 2,000 kilowatts; hence corresponding data are given for turbines. Power-plant cost includes everything from real estate up to complete installation of all auxiliaries. The tables follow.

Cost of installation of steam-turbine and of gas-engine power plants.[a]

Size of plant.	Size of units.	Number of units.	Cost per kilowatt of installing—	
			Turbine.	Gas engine.
Kilowatts.	*Kilowatts.*			
2,000	500	4	$82.00	$133.00
4,000	1,000	4	71.00	115.00
6,000	2,000	3	67.00	106.00
8,000	2,000	4	64.50	104.00
10,000	2,000	5	62.50	102.50
10,000	6,000 2,000	1 2	61.00	....

[a] The fixed charges for each type of plant were as follows: Interest, 5 per cent; taxes and insurance, 2 per cent; amortization, 3.5 per cent; total, 10.5 per cent.

Operating cost of gas-engine and of steam-turbine power plants.

COST ITEMS FOR GAS-ENGINE PLANT.[a]

Size of plant.	Labor.	Repairs and maintenance.	Oil, waste, and supplies.	Fuel.[b]	Total operating cost.	Fixed charges.	Total.
Kilowatts.							
2,000	0.163	0.044	0.032	0.27	0.509	0.236	0.745
4,000	.145	.039	.029	.27	.483	.204	.687
6,000	.130	.035	.026	.27	.461	.188	.649
8,000	.124	.034	.025	.27	.453	.184	.637
10,000	.123	.033	.025	.27	.451	.182	.633

COST ITEMS FOR TURBINE PLANT.[a]

2,000	0.106	0.019	0.020	0.41	0.555	0.133	0.688
4,000	.088	.017	.017	.36	.482	.115	.597
6,000	.072	.017	.014	.338	.441	.108	.549
8,000	.067	.016	.013	.332	.428	.104	.532
[c] 10,000	.066	.016	.013	.33	.425	.101	.526
[d] 10,000	.064	.0155	.0125	.323	.415	.099	.514

[a] In cents per kilowatt-hour.

[b] At $3 a ton.

[c] Consisting of five 2,000-kilowatt units.

[d] Consisting of one 6,000-kilowatt unit and two 2,000-kilowatt units.

In considering items pertaining to the two 10,000-kilowatt turbine plants, it should be noticed that the plant with the larger units has lower costs for each item. A similar arrangement might be made for the other turbine plants, with a decreased cost resulting; for example, the plants might be arranged as follows:

2,000-kilowatt plant in one 1,000-kilowatt unit and two 500-kilowatt units.

4,000-kilowatt plant in one 2,000-kilowatt unit and two 1,000-kilowatt units.

6,000-kilowatt plant in one 3,000-kilowatt, one 2,000-kilowatt, and one 1,000-kilowatt unit.

8,000-kilowatt plant in one 4,000-kilowatt unit and two 2,000-kilowatt units.

If the heating value of the coal is assumed to be 13,000 British thermal units per pound for all prices of coal, the only item in the operating cost affected by the varying price would be fuel cost. For example, in a 4,000-kilowatt turbine plant the effect of varying fuel prices might be as indicated below:

Cost of coal per ton.	Fuel cost per kilowatt-hour.
$1	$0.12
2	.24
3	.36
4	.48

In the table following are given some approximate cost figures for hydroelectric power when used for electric furnaces or electrochemical purposes, with a high load factor:

Cost of electric power for electric furnaces or electrochemical purposes with a high-load factor.

Location of plant.	Power company.	Nature of power.	Cost per kilowatt-year.	Product at the present time.
Braintree, England	Lakes & Elliott Steel Foundry.	Gas engine	$110	Steel.
Sheffield, England	Municipal System	Steam	87	Do.
La Praz, Savoie, France	Electrometallurgical Co. of France.	Hydroelectric	16	Aluminum, steel, carbide.
Livet, Isère, France	Keller, Leleux & Co	do	13	Ferro-alloy.
Ugine, Savoie, France	Girod Electrometallurgical Co.	do	18	Ferro-alloy, steel.
Bonn, Germany	Municipal System	Steam	92	Steel.
Remsheid, Germany	Lindenber Steel Co	do	87	Do.
Volklingen, Germany	Röchling Iron & Steel Co	Steam, gas	83	Do.
Meraker, Norway	Meraker Electric Smelting Co.	Hydroelectric	8	Ferro-alloys, carbide.
Notodden, Norway	Norwegian Saltpeter Co	do	7	Nitrates.
Rjukan, Norway	do	do	5	Do.
Tyssedal, Hardanger, Norway.	Tyssedal Power Co	do	10	Carbide, cyanamide.
Trollhättan, Sweden	Royal Power Plant	do	9 to 12	Iron, zinc, ferroalloy, paper.
South Verron, Vt	Connecticut River Power Co.	Water and steam	53	General.
Shelburne Falls, Mass	do	Water (secondary)	29	Do.
Turners Falls, Mass	Turner Falls Power Co	Water and steam	60	Do.
Do	do	Water (secondary)	26	Do.
Rumford Falls, Me	Rumford Falls Power Co	Hydroelectric	26	Paper.
Niagara Falls, U. S		do	26	Electrochemical.
Niagara Falls, Canada		do	20	Do.
South Carolina	Southern Power Co	do	25	Nitrates.
South Chicago, Ill	Illinois Steel Co	Steam, gas	43	Steel.
South Carolina	Southern Aluminum Co	Hydroelectric	25	Aluminum.
Snake River, Idaho	Southern Idaho Power Co.	do	12	General.
Heroult, Cal	Northern California Power Co.	do	16	Pig iron.

OPERATING CONDITIONS OF ELECTRIC FURNACES.

In the operation of an electric furnace one or more of the following conditions may be encountered:

A high enough temperature may not be reached in consequence of one of the following conditions:

1. The furnace may be "underpowered," that is, may not have enough electric current supplied to it, and this in turn may be due to lack of either power-line supply, transformer capacity, or insufficient voltage.
2. The material to be treated may be fed too rapidly.
3. The radiation losses may be too great.

Then, too, the temperature may be too high. With furnaces using voltage control this fault may be remedied by cutting down the voltage of the current used, but if a constant voltage be used and the temperature is too high about the only remedy is to feed in more charge. If this procedure will remedy the defect it indicates that the furnace has a capacity greater than that which has been calculated for it. However, an "overpowered" furnace is generally short lived, as the walls are unable to conduct the heat away fast enough to prevent their destruction through fusion. Then, too, as is self-evident, the higher the temperature the greater will be the heat losses through the furnace walls and through the electrodes. Hence, if there is no advantage to be gained from a temperature higher than is needed for the necessary reactions of the process, it can be said that if in operating an electric furnace an excessive temperature is obtained an error has been made in calculating the size of the furnace or in the amount of energy needed. However, as is also self-evident if the excess heat can be absorbed by a faster feeding of the material to be smelted the heat losses per pound of material smelted will be less, for the heat losses through the electrodes and walls are continuous, and hence are less per pound of material smelted if 20 pounds be treated per minute than if only 10 pounds be treated.

CONCLUSION.

In conclusion the authors repeat that their object has been not to present a technical discussion of the electric furnace, but to acquaint the layman, so to speak, with some of the most important essentials in connection with the use and construction of the electric furnace as used in metallurgical work and to assist those who are unfamiliar with the subject to a better understanding of the processes described in parts II and III of this bulletin and in Bulletin 67 on "Electric Furnaces for Making Iron and Steel."

PART II. THE SMELTING OF METALS IN THE ELECTRIC FURNACE.

By Dorsey A. Lyon and Robert M. Keeney.

INTRODUCTION.

The object of Part II of this bulletin is to present briefly a statement of the extent to which the electric furnace has been applied to the metallurgy of metals when the product is in the form of the metal and not of a ferro-alloy. For example, the metals copper and zinc are discussed in this part and the ferro-alloys, such as ferrochrome and ferrotungsten, are discussed in Part III. No attempt is made to present exhaustively the details of each particular process, as persons desiring such information can obtain it from the references given.

Under this part there is discussed the electric smelting of the ores of aluminum, copper, gold and silver, iron, lead, complex sulphides, and zinc. The subject of iron has been treated briefly, as compared with its importance, because it has already been discussed fully in Bulletin 67.[a]

ALUMINUM.

INTRODUCTION.

In the manufacture of aluminum the electric furnace has a field entirely its own, for there is no process by which alumina is reduced to aluminum in a combustion furnace. In the metallurgy of aluminum, as stated in Part I of this bulletin, the electric current not only supplies the necessary heat, but also reduces the metal from the ore. The first application of electrolysis to the reduction of aluminum was in 1864 when Bunsen and Deville, each working independently, obtained the metal by the electrolysis of fused aluminum chloride.[b] Previous to the introduction of the present method the aluminum was obtained chiefly through the reduction of the halide salts of the metal with metallic sodium.

In 1884 the Cowles process was patented, in which alumina was reduced with carbon in the presence of copper in an electric furnace of the resistance type. An alloy[c] of aluminum and copper was the product. It was known then that alumina could be reduced to aluminum as a result of being heated with carbon to a temperature higher than 2,100° C., but all of the aluminum formed was mixed with aluminum carbide, from which it was removed by a refining process. In the Cowles process the copper was used to prevent the formation of aluminum carbide, but of course the process had the objection that the aluminum was not obtained as pure metal but as an alloy.

---

[a] Lyon, D. A., and Keeney, R. M., Electric furnaces for making iron and steel: Bull. 67, Bureau of Mines, 1913, 142 pp., 36 figs.

[b] Thompson, M. D., Applied electrochemistry, 1911, p. 228.

[c] U. S. patent 319795.

In 1886 Hall[a] found that alumina dissolved in a molten mixture of aluminum fluoride and the fluoride of another metal formed an electrolyte which could be decomposed by the electric current accordding to the reaction $Al_2O_3=2Al+3O$. About the same time that Hall made his discovery, Héroult in France made a similar independent discovery.

PREREQUISITES FOR THE PRODUCTION OF ALUMINUM BY PRESENT METHODS.

Although aluminum is one of the most abundant of the elements that make up the earth's crust, nevertheless those of its ores that are suited to the process of aluminum manufacture, as carried on at present, are comparatively scarce. About the only one now used for this purpose is bauxite. The great bulk of that produced in the United States is mined in Arkansas and Tennessee. Phalen[b] states that some bauxite is now mined in central Georgia.

PROCESSES FOR PURIFYING BAUXITE.

As all the impurities in the alumina pass into the metal produced, it is necessary in both the Hall and the Héroult processes to use alumina as pure as possible. This is why the Bayer process found considerable application both here and abroad for the purification of bauxite. In this process the bauxite is fused with the carbonate or sulphate of sodium and the fused mass is washed with water; then the sodium aluminate obtained in solution is decomposed by adding aluminum hydrate and constantly stirring. Richards[c] states that the decomposition of the solution goes on until the quantity of alumina remaining in solution is to the sodium protoxide as 1 to 6. This precipitation takes place in the cold, and the pulverent aluminum hydrate separated out is easily soluble in acids. The alkaline solution remaining is concentrated by evaporation, taken up by ground bauxite, dried, calcined, melted, and thus goes through the process again.

---

[a] U. S. patents 400664 and 400666.

[b] Phalen, W. C., Bauxite and aluminum: Mineral Resources U. S. for 1911, U. S. Geol. Survey, 1912, p. 928.

[c] Richards, J. W., Aluminum, its properties, metallurgy, and alloys, 3d ed., 1896, p. 144.

Hall also invented and patented at least two processes for this purpose, including the lime process of wet chemical treatment (U. S. patent 663167, Dec. 4, 1900), which was installed at East St. Louis, and a process whereby the bauxite is mixed with a small percentage of carbon and calcined, and after calcination is again mixed with about 8 to 10 per cent of carbon, some ferric oxide, possibly some sort of a flux being added. The impurities such as iron and silicon are reduced, and form ferrosilicon of impure grade, which sinks to the bottom of the electric furnace, leaving the purified alumina at the top. After the alumina has cooled, it is separated from the ferrosilicon by electromagnetic methods if necessary. In the patent specification, it is stated that aluminum powder is also added, but this is not now thought necessary. In England, the British Aluminum Co. (Ltd.) purify bauxite by dissolving it in caustic soda and then precipitating the alumina by the addition of some previously precipitated alumina.[a]

HALL PROCESS FOR PRODUCING ALUMINUM.

Although more than 20,000 tons of aluminum is produced each year in the electric furnace, little published information is available concerning the methods of manufacture, as all manufacturers try to keep their processes secret. In this country practically all of the aluminum produced is obtained by the use of the Hall process. The essential facts regarding this process are as follows: The ore (bauxite) is first purified by being treated either by the lime process or the electric-furnace process. It is then charged into an electric furnace containing a bath of cryolite or a mixture of aluminum fluoride with the fluoride of another metal, the bath being kept molten by the heat generated by the passage of the electric current. The alumina is thus decomposed into aluminum and oxygen by the electrolyzing action of the direct current. A concise description of the process used in practice is given by Neumann and Olsen[b] from whose article the following information is quoted:

> A photograph of an aluminum cell has been published only once, so far as is known, by J. W. Richards;[c] the cell shown is evidently a cell of Charles M. Hall, as used some years ago. The illustration shows 20 round anodes in two parallel rows in a high iron box. Quite detailed notes illustrated by sectional diagrams were also given later by Winteler.[d] The cells described by Winteler are also rectangular, and are also provided with a double row of carbon electrodes. More recently, circular cells have been introduced, the anodes being distributed over the whole surface.

---

[a] Cachu, William, London Elec. Rev., 1911, vol. 68, p. 99.

[b] Neumann, B., and Olsen, H., Production of aluminum as a laboratory experiment: Met. and Chem. Eng., vol. 7, 1910, p. 185.

[c] Electrochemical Industry, vol. 1, 1903, p. 100.

[d] Winteler, Aluminium Industrie, 1903.

HÉROULT PROCESS FOR THE MANUFACTURE OF ALUMINUM.

In principle, the Héroult process is the same as the Hall process, the reported differences being in the composition of the electrolyte and possibly in the shape of the furnace. In fact, the two processes are so similar that when the discovery of the reaction was made simultaneously, there was no patent litigation, but the Hall Company took the American field and the Héroult people the European, a condition that was maintained until recently, when the last of the Hall and allied patents expired in the United States. Now the Héroult interests are erecting a plant in North Carolina.

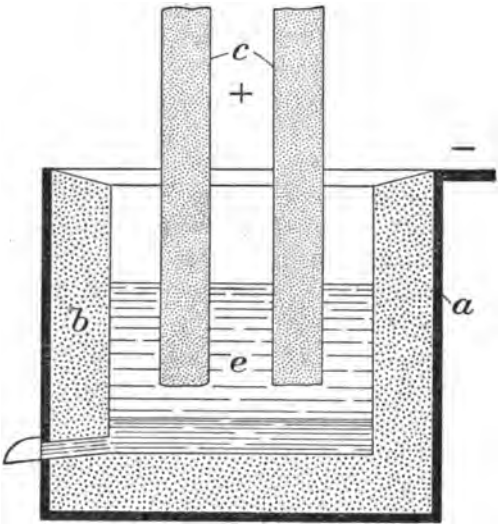


FIGURE 37.—Aluminum furnace, *a*, shell; *b*, lining; *c*, anodes; *e*, bath.

In Europe at the present time the manufacture of aluminum is conducted exclusively in furnaces (see fig. 37) having a carbon block as the cathode, forming the bottom of the furnace, upon which the molten aluminum collects, and several upper carbon anodes, while the bath is kept molten entirely by the heat generated due to the passage of the electric current. The cross section is in all cases rectangular. The furnaces seen recently by one of the writers at a French aluminum plant were rectangular and of the general shape of the Héroult steel furnace, but not so large. They were about 5 feet long, 3 feet wide, and 3 feet deep externally. Each furnace rested on the floor of the building without special foundations, so that furnaces could be picked up and moved around readily with a crane. There were eight carbon anodes projecting into the bath and connected to the positive side of the circuit, while the electrodes in the carbon bottom are connected to the negative side of the circuit. There is an electrode in the bottom corresponding to each of the anodes. In this case the bottom is only partially covered by the molten aluminum.

A second type of furnace has a bottom composed of a mixture of tar and ground coke or electrode waste, which is rammed in around four large iron plates connected to the negative side of the circuit. There are four rows of anodes containing six to eight electrodes per row. In both types of furnace the bottom is inclined toward the tap hole, and each electrode is arranged so that it can be regulated independently of the others.

In the Héroult as in the Hall process the composition of the bath is kept secret, but in both processes the specific gravity of the bath must be less than that of the metal, so that the latter can collect on the bottom. Cryolite melts at 1,000° C., but its melting point is reduced to 915° C. by the addition of 5 per cent alumina. By the use of calcium fluoride the melting point of cryolite can be further reduced to 800° C. Cryolite has a specific gravity of 2.92 when solid and 2.08 when liquid, whereas aluminum has a specific gravity of 2.6 when solid and 2.54 when liquid. It is not considered advisable to have more than 25 per cent of aluminum, in the form of alumina, in the molten bath. Although aluminum fluoride can also be used for lowering the melting point, the most common flux is calcium fluoride.

Theoretically, 42 grams (0.092 pound) of aluminum per kilowatt-hour should be produced by the electrolysis of alumina in a bath of cryolite. Practically, the foreign manufacturers using the Héroult process make 30 grams (0.066 pound) of aluminum per kilowatt-hour, which gives an efficiency of 71 per cent.

The furnaces take about 75 kilowatts each and produce from 50 kilograms (110 pounds) to 55 kilograms (121 pounds) per 24 hours. The voltage used is from 8 to 10 volts and the density of current from 1.5 to 3 amperes per square centimeter. The consumption of alumina per pound of finished aluminum is theoretically 1.888 pounds and practically 2 pounds. For each pound of aluminum produced there is a consumption of 0.1 pound of cryolite and 0.9 pound of carbon anodes.

The main progress in aluminum manufacture, as far as can be determined, has been in the purification of the bauxite into alumina before it is charged into the electrolytic cell, mention of which has already been made.

SERPEK PROCESS.

A new process, the Serpek, has been devised and is being introduced in Europe. In this process bauxite is heated to a temperature sufficient to cause the formation of aluminum nitride, which is decomposed by the action of water into alumina and ammonia, according to the reaction $2\,AlN + 3H_2O = Al_2O_3 + 2NH_3$. For the preliminary reaction an electric furnace is not absolutely necessary, as producer gas can be used as a fuel, but of course an electric furnace is used to reduce the refined alumina to metallic aluminum. The process thus provides a method for the fixation of nitrogen and for the purification of bauxite to produce pure alumina for the electrolytic cell.

The raw bauxite is first calcined by being passed through a revolving cylindrical kiln similar to a cement kiln. The calcined bauxite passes by gravity to another similar kiln, before entering which it is mixed with carbon and then treated with nitrogen. Halfway down the lower kiln is a detachable electric resistance furnace which is intended to raise the temperature to 1,800° to 1,900° C. The material is discharged from the lower end of this kiln into an air-tight receiver. Producer gas, consisting of one-third carbon monoxide and two-thirds nitrogen, is introduced at the lower end of the lower kiln. This gas enters at a temperature of 400° C., but when it reaches the electrically heated part of the furnace and attains a temperature of 1,800° C., it reacts upon the charge to form aluminum nitride.

PRESENT STATUS OF ALUMINUM MANUFACTURE IN THE UNITED STATES.

The following table,[a] showing the production of aluminum since the beginning of the industry in 1883, and the consumption of the metal since 1904, gives an idea of the magnitude of the industry in this country:

Production of aluminum in the United States, 1883–1904.

Year.	Pounds.
1883	83
1884	150
1885	283
1886	3,000
1887	18,000
1888	19,000
1889	47,468
1890	61,281
1891	150,000
1892	259,885
1893	333,629
1894	550,000
1895	920,000
1896	1,300,000
1897	4,000,000
1898	5,200,000
1899	6,500,000
1900	7,150,000
1901	7,150,000
1902	7,300,000
1903	7,500,000
1904	[b] 8,600,000
1905	[b] 11,347,000
1906	[b] 14,910,000
1907	[b] 17,211,000
1908	[b] 11,152,000
1909	[b] 34,210,000
1910	[b] 47,734,000
1911	[b] 46,125,000
Total	239,751,779

Until recently there was only one company producing aluminum in the United States, and that company controlled the Hall patents. Now that these patents have expired, as before stated, French interests are erecting a plant at Whitney on the Yadkin River in North Carolina. Work is being pushed rapidly on this plant, which is to be capable of producing 5,000 tons annually.

In 1907, the company controlling the Hall patents had a total plant capacity of about 57,000 kilowatts, of which 45,000 was in the United

---

[a] Phalen, W. C., Bauxite and aluminum: Mineral Resources U. S. for 1911, U. S. Geol. Survey, 1912, p. 932.

[b] Consumption.

States and 12,000 in Canada. The company failed to get permission from Congress to increase some of its water-power developments and at present about 4,000,000 pounds of aluminum is annually imported into the United States, as this company alone can not supply the domestic demand. It is, however, building a plant in Tennessee that will increase its productive capacity considerably. The demand for aluminum has increased rapidly during the past few years, and as there are no longer any patent restrictions, it is probable that other companies will begin manufacture in the United States.

FACTORS GOVERNING GROWTH OF ALUMINUM INDUSTRY.

As can be readily seen from what has already been stated on this subject, the growth of the aluminum industry will depend, among other things, upon the discovery of new ores of aluminum; that is, ores that can be used in the production of aluminum by the processes now employed for that purpose, or upon the development of processes for the treatment of ores that are not now suited to the Héroult or Hall processes, or to processes similar to them.

NEW SOURCES OF ALUMINA.

As before stated, bauxite is practically the only ore now used for the production of aluminum. However, Phalen[a] states that experiments with alunite, deposits of which occur near Marysvale, Utah, and in Colorado, California, Arizona, and Nevada, indicate that it may at some future time become an important source of alumina.

The mineral alunite is a hydrous sulphate of aluminum and potassium, having the formula $K_2O.3Al_2O_3.4SO_3.6H_2O$, and according to laboratory experiments made by Schaller of the Geological Survey contains, when ignited, 32.7 per cent of available potassium sulphate, which can be extracted by simple water leaching and evaporation, thus leaving a residue of 67.3 per cent, which consists of nearly pure aluminum oxide. Such being the case, it would at first thought seem as if this ore would be valuable both for its potash content and for the aluminum that it contains. As a matter of fact, as pointed out in the report of the Geological Survey, the mineral has attracted attention as a possible source of potash. However, as Phalen states, present known deposits are so far from Eastern markets that alunite ores may not be able to compete with Eastern bauxite ores. But as bauxite contains a considerable proportion of iron oxide, silica, and titanium oxide, and requires purifying before being reduced to metallic aluminum, whereas the residue remaining after the leaching
ignited alunite consists of practically pure aluminum oxide, it
ld seem that this advantage, together with the fact that the

---

[a] en, W. C., Bauxite and aluminum: Mineral Resources U. S. for 1911, U. S. Geol. Survey, 1912, 26.

available potassium sulphate that alunite contains is a valuable by-product, would more than offset added transportation charges to Eastern markets.

PROCESSES FOR PRODUCING ALUMINUM FROM ORES OTHER THAN OXIDES.

Patents covering the production of aluminum from molten electrolytes seem to cover every possible method of obtaining aluminum from its ores,[a] so that one would think that little more could be done along this line; but, as in other branches of metallurgical work, new ideas are being constantly advanced and patents are obtained on new and generally untried inventions until they seem to be without end.

As previously stated, bauxite, which is practically the only ore used for the production of aluminum, is found in comparatively few places. Moreover, it not only has to be transported long distances, but also requires a costly preliminary treatment for the purpose of freeing it as far as possible from all constituents other than alumina. Aluminum silicates, on the other hand, can be had almost anywhere, and it would therefore seem that the logical thing to do, as regards discovering new sources from which aluminum can be obtained, would be to perfect commercially feasible processes for the production of the metal from those aluminum minerals that are so common. Considerable experimental work of this sort has already been done and several patents have been granted on processes for extracting aluminum from ores containing it in some form other than the oxide.

TONE'S METHOD.

The method proposed by Tone[b] consists of two steps. In the first step the aluminum-bearing ore is mixed with the proper quantity of carbon, and the aluminum is reduced to aluminum carbide. The aluminum carbide is then mixed with some other ore—silica, for example. The aluminum carbide and the silica are to be in the proportions expressed by the equation $2Al_4C_3+3SiO_2=8Al.3Si+6CO.$, and the mixture is fused in an electric furnace yielding, as shown by the above equation, a silicon-aluminum alloy.

If metallic aluminum be desired, the aluminum carbide is mixed with aluminum oxide in the proportion expressed by the chemical equation $Al_4C_3+Al_2O_3=6Al+3CO$. As has been shown by Hutton and Petavel,[c] although the oxide of aluminum (alumina) can be readily reduced to the metal by carbon, yet the temperature at which the reduction takes place is sufficiently high to volatilize the metal. For this reason, if for no other (as, for example, the reduction of other elements contained in the ore, which would alloy with the aluminum), Tone claims that it is better to divide the process into two parts, thus entailing little or no volatilization loss, and that the production of carbides with the electric furnace is highly efficient. However, as will be noted, the use of aluminum oxide is an essential part of the process where the production of metallic aluminum is desired.

---

[a] See digest of patents taken out prior to July, 1902, in Electrochemical Industry, vol. 2, 1904, pp. 165, 166, 210.

[b] U. S. Patent 961913, June 21, 1910.

[c] Hutton, R. S., and Petavel, J. E. On the direct reduction of alumina by carbon: Electrochem. and Met. Ind., vol. 6, 1908, p. 104.

Tone has also taken out two other patents on the production of aluminum from silicates. In one of these (No. 906,338) kaolin is mixed with carbon for the purpose of reducing the silica but not the alumina. The mixture is fused in an electric furnace, the products being alumina and silicon as shown by the following equation:

$$Al_2O_3+SiO_2+4C=Al_2O_3+2Si+4CO$$

The alumina after separation from the silicon can be used for the production of aluminum by the usual methods. Tone states that the reaction shown above may be facilitated by adding base metals or ore to the charge, as the base metal alloys with the silicon and so brings about a more complete reduction of the silicon. For example, if 222 parts of calcined kaolin be mixed with 48 parts of carbon and 56 parts of iron, then the reaction in the electric furnace is shown by the following equation:

$$Al_2O_3.2SiO_2+4C+Fe=Al_2O_3+FeSi_2+4CO$$

After the fused product has been tapped from the furnace, the silicide is separated from the alumina, after which the alumina may be treated for the production of aluminum in the usual manner.

Alf-Sinding Larsen has also taken out a patent (U. S. No. 927758) that closely resembles that of Tone. In his process he proposes to fuse silicates of aluminum in an electric furnace in contact with iron (scrap iron or iron ore) and coke. The product of the fusion is ferrosilicon and alumina. The alumina can then be treated in the usual manner for the production of aluminum.

BETTS'S PROCESS.

Briefly stated, the process proposed by Betts consists of the following steps:

1. Iron ore and aluminum ore such as bauxite or kaolin are charged with fuel into a blast furnace, similar to an iron blast furnace, but operated at a higher temperature than the latter. The product is iron-aluminum-silicon.

2. As aluminum is the most readily oxidized, sulphurized, or chloridized metal of the iron-aluminum-silicon compound, aluminum may

be extracted by means of either oxidizing, sulphurizing, or chloridizing agents. For example, by treating the iron-aluminum-silicon metal with silica at a high temperature, the aluminum of the metal would be oxidized by the oxygen of the silica, and there would be formed pure aluminum oxide and ferrosilicon, provided the iron ore is free from lime and magnesia.

3. Betts claims that aluminum sulphide can be more readily and cheaply reduced to aluminum than can the oxide (alumina), and so instead of reducing the alumina to metallic aluminum, as is done in the Hall and Héroult processes, he proposes to treat it with iron sulphide, thus forming aluminum sulphide. This part of the process however, is carried out in two steps. The alloy is first treated with an insufficient quantity of iron sulphide to react with the aluminum present, resulting in practically pure aluminum sulphide. This aluminum sulphide is then reduced by electrolysis to aluminum and sulphur.

As the alloy remaining after the treatment in the second step by fusion with silica still contains considerable aluminum, it is further treated with an excess of iron sulphide. The result of this treatment is a matte, which is then used alone or with additional fresh iron sulphide in the next treatment of the aluminum alloy.

IRON.

PRESENT STATUS OF ELECTRIC FURNACE IN SMELTING IRON ORES.

USE OF COKE AND CHARCOAL.

As is well known, of the coke charged into an iron blast furnace, only about two-thirds is used for producing the heat necessary for carrying on the process, the other one-third being used as a reducing agent. Therefore, if the electric furnace is used for the smelting of iron ores, only enough carbon has to be supplied to unite with the oxygen of the ore, or in other words, to reduce it, and for this reason the smelting of iron ores in the electric furnace is of much importance to the Western Coast States, for there are found iron-ore deposits comparatively large, but not suitable blast-furnace coking coals, and so the cost of coke makes ordinary blast-furnace smelting too expensive. However, it is, of course, necessary to supply carbon in some form as a reducing agent, and even though only one-third as much carbon is required for this purpose as is required in ordinary blast-furnace practice, it may be impossible to obtain even this amount at such a cost as will permit the use of the electric furnace. So far only coke and charcoal have been tried to any extent as reducing agents in the reduction of iron ores in the electric furnace, and for a time it was thought that coke could not be successfully used, as several trial runs at Tröllhattan on coke were not successful and later the plant at Hardanger, Norway, where coke was used as a reducing agent, after being in operation for about nine months, was forced to close down, owing to the fact that with coke the quantity of pig iron that could be produced per kilowatt-year of electrical energy expended was not nearly as great as can be produced when charcoal is used. It was stated that the reason for this was that coke, especially hot coke, is a much better conductor of electricity than is charcoal. For this reason when coke is used the resistance of the charge becomes lowered, and as the smelting in the electric iron reduction furnace is done by the heat produced by the resistance encountered by the electric current in passing through the charge between the electrodes, more electrical energy is required to produce the same amount of heat. However, Profs. H. L. Vogt and P. Farup,[a] of the Norwegian electrometallurgical commission, reporting on the causes of the economic failure of this plant do not attribute the same to the use of coke, but "partly to the nature of the ores treated and partly to their low iron content, conjointly with the unsatisfactory condition of the agglomerating roasting oven, and several parts of the electrical equipment." They state that an "excellent quality of pig iron can be produced" with coke, and that "the consumption of carbon is the same whether charcoal or coke is employed;" also that the consumption of electrical energy was that originally computed by them for both poor and rich ores.

On the other hand, Engineer Gustaf Oedquist, in a statement made before the Christiania Polyteknik Forening, says:

> The committee is of the opinion that the type of smelter used did not conduce to the unfavorable results at Hardanger. I am of a different opinion. The reason why it is not adapted to coke consists in the greater variation in the electrical resistance in the furnace itself by the use of coke, owing to which the average load as well as the production is diminished. To which must be added that the larger quantity of limestone thereby necessitated contributes to a lesser production of pig iron per horsepower-year.

Considerable experimenting has also been done with coke as a reducing agent by the Noble Electric Steel Co. at Heroult, Cal. In his summary of deductions Mr. Crawford, the plant manager, states:[b]

> 1. Any ordinary grade of coke, by crushing it, can be used satisfactorily from both a metallurgical and an electrical standpoint to produce any normal grade of pig iron. But, depending on its porosity and crushing strength and its analysis, there is for each variety a size to be determined by experiment which will give from all standpoints best operating conditions.
>
> 2. Soft, porous cokes are to be preferred over hard, dense cokes, because the former can be fed in larger pieces and still insure homogeneity of mixture when the burden descends to the smelting zone. Further, they cost less to crush, and there is less loss in fines and flue dust because of the larger size which can be used. For ore crushed

---

[a] Anon., Electrothermic iron-ore smelting in Norway: Eng. and Min. Jour., vol. 98, July 25, 1914, p. 158.

[b] Crawford, John, Discussion of paper by Robert M. Keeney on "Pig steel from ore in the electric furnace.": Bull. Am. Inst. Min. Eng., June, 1914, p. 1289.

to pass a 2¾-inch grizzly, a soft, porous coke gives best results when crushed to pass a 1½-inch grizzly. Certain hard, dense cokes had to be crushed to pass a ¾-inch grizzly.

3. If the coke is of the proper size when it reaches the smelting zone, operations may be carried on with as high voltage, low current densities, good power factor, and as cool a roof when using coke as when using charcoal.

4. The power consumption per unit of production is higher with coke as a reducing agent than with charcoal, but the increase is due to the extra amount of slag made. This depends on the composition and amount of ash in the coke and the amount of sulphur in the coke.

5. The carbon consumption per unit of production is higher with coke than with charcoal. This is due partly to the greater flue-dust losses from crushed coke than from lump charcoal, and partly to the formation of carbides, in the high-lime, desulphurizing slag, all of which are not subsequently decomposed.

6. If electrodes are regulated to form a free-burning arc, the use of coke has no bearing on the electrode consumption. If, however, electrodes are inserted in the charge to form a submerged arc, as is our practice, the consumption of electrode material is considerably greater, especially with graphite electrodes. This is due principally to the greater abrasive action of coke than charcoal, though partly also to the attack of the lime slags on the electrode material. We found the electrode loss from breakage (using 12-inch graphite electrodes) very excessive, doubtless due in part to the greater density of the burden when using crushed coke as against lump charcoal. On this account, after carrying our experiments far enough to demonstrate the commercial feasibility of operating on coke, we have shut our furnaces down pending alterations to permit the use of 24-inch carbon electrodes, which, besides being stronger, will better resist the abrasive action of the burden.

7. With a coke running 1.25 per cent sulphur we had little difficulty in keeping the sulphur in the pig below 0.05 per cent, and much of the iron made was under 0.03 per cent sulphur.

8. No trouble was found in making foundry irons up to 3.50 per cent silicon or higher if desired. In fact, on account of its high, easily reduced, siliceous ash, coke will reduce a high-silicon iron somewhat more readily than charcoal.

9. Except for a somewhat more open grain, no difference has been noted thus far in the physical characteristics of iron made with coke and iron made with charcoal.

10. Crushed coke, especially when high in ash and with a large percentage of fines present, has a tendency to cause the burden to hang. This we believe would prohibit its use successfully in a furnace of the shaft type. However, in the rectangular furnaces there is an opportunity to dislodge scaffolds by barring down, if the hang is of any duration. There are several ways in which the presence of a hang-up can be detected before it has become serious. A mixture of 15 to 25 per cent of lump charcoal with the coke is quite effective in keeping the burden from hanging up.

In conclusion, we may say that coke has nothing to recommend it over charcoal for an electric-furnace reducing material, excepting the difference in price. However, "black-butts," screenings, and even breeze if the dust is removed, can be mixed to make a satisfactory reducing material. As such grades of coke can usually be secured at a very attractive price, this may more than offset the disadvantages of its use.

The writer apologizes for offering the above statements as "glittering generalities" unsubstantiated by definite figures, but, since the data obtained varied considerably with the chemical and physical properties of each coke tried and the size to which it was crushed, even a synopsis of this rather voluminous data is considered beyond the scope of this discussion.

Inasmuch as charcoal and coke are the only practical reducing agents known at present for use on a large scale, and as it would seem from what has just been stated that it is impractical to use coke in a

furnace of the shaft type, the electric iron reduction shaft furnace is necessarily limited to the use of charcoal. Hence it is necessary that such a furnace be located in close proximity to a well-timbered region, where charcoal as well as electric power can be produced at a low cost.

POSSIBLE USE OF CRUDE OIL AS A REDUCING AGENT.

In southern California and in other Western States there are rather large iron deposits of high-grade ore but coke is too expensive to permit ordinary blast-furnace smelting and the use of charcoal for electric-furnace work is entirely out of the question, as there are no forests to furnish the wood necessary for its production. On the other hand, crude oil is generally rather plentiful and comparatively cheap in such districts, especially in California.

Aside from the possible use of oil in connection with electric-furnace work, those interested in the subject have for years been considering the possibility of using crude oil as a reducing agent. So far as the authors know, the oil has not as yet been so used successfully. That the carbon and the hydrogen of the oil will reduce iron oxides is self-evident, but as yet no one seems to have been able to solve the problem of bringing the ore and the oil together at the proper temperature. As a result of a preliminary investigation conducted by the Bureau of Mines as to the possibility of using crude oil as a reducing agent, it seems as if about the only manner in which crude oil may be used for this purpose is first to convert it into a fixed gas and then to introduce this into the crucible of an electric furnace, thus preheating the gas to such a temperature that it will effectively reduce the iron oxides as it passes up through the shaft of the furnace. Be that as it may, it is to be sincerely hoped that ultimately a suitable process may be devised whereby oil may be used as a reducing agent, and thus broaden the field for the possible application of the electric furnace in the reduction of iron ores.

USE OF ELECTRIC IRON REDUCTION FURNACE AT PRESENT.

That the electric furnace has been successful in the smelting of iron ores in districts where the conditions are favorable is shown by the fact that 10 furnaces of the Swedish type with a total capacity of about 22,000 kilowatts have been erected in Sweden, Norway, and Switzerland. In this country there is one iron plant of two electric furnaces with a total capacity of 5,000 kilowatts in operation at Heroult, Cal. The type of furnace used in California is different from that used in Sweden, owing to the fact that a different grade of iron is desired from that produced in Sweden; that is, in Sweden a metal is produced that is low in silicon and carbon and particularly well suited to steel making, whereas in California the demand is for a soft gray foundry iron.

As to the advantages of the metal produced in a Swedish type of furnace for steel making, they have been stated by Keeney[a] to be as follows:

1. That it can be converted into steel with greater facility and at a lower cost.
2. That it admits of greater economy in power consumption.
3. That it admits of greater economy in reducing material.
4. That the carbon content can be controlled within a limit of 2.20 per cent maximum.
5. That the losses of iron in the slag will not exceed reasonable limits, say 6 per cent FeO.

A metal has been made by the Noble Electric Steel Co., "quite similar in both appearance and analysis to the pig iron which was at that time reported as being used successfully for steel making in Sweden," concerning the use of which Crawford[b] reports as follows:

> Stimulated by the results which were being obtained in Sweden we made considerable effort to induce steel makers on the Pacific coast to try it. Finally by making a very attractive price we induced one firm to use it. This concern operates both basic and acid open-hearths for making concrete reinforcing steel. The report of the works superintendent on it was rather indefinite but not enthusiastic. He said "It worked pretty well, but normal pig iron was more satisfactory." Since that time we have sold this concern about 1,000 tons of normal low-silicon pig iron and also a few odd carloads of white iron which approached in analysis pig steel. They advise that no difference is noted in the working of normal electric-furnace pig iron as compared to normal blast-furnace iron of similar analysis. The pig iron brought the market price, but the pig steel always had to be offered on more favorable terms, and even at a reduced price it did not call forth any repeat orders.
>
> These remarks are not intended to be construed as a contradiction of the favorable reception which pig steel has been accorded by the Swedish steel men, but it does seem to indicate that to gain the advantages claimed pig steel must be used "according to prescription" and a good deal of "missionary work" might be necessary before American steel makers, who have no patriotic interest in the matter, would do the necessary experimenting to prove the advantages claimed.

ENGINEERS' REPORT OF THE EXPERIMENTAL WORK AT TROLLHÄTTAN.

The engineers in charge of the experimental work at Trollhättan made the following statements in their final report according to the Iron and Coal Trades Review:[c]

QUALITY OF PIG IRON PRODUCED IN ELECTRIC FURNACE.

The silicon content does not vary more than in an ordinary blast furnace. T
phosphorus content is lower than with the same quality of charge in a
blast furnace; this is due to the lower consumption of charcoal.
of sulphur is, however, slightly higher in the electric furnace.
observed that both at Trollhättan and at Hagfors unroasted ores h
out any difficulty arising from the sulphur present.

---

[a] Keeney, R. M., Pig steel from ore in the electric furnace: Bull. Am. Inst. Mi
349-367. Discussion, Ibid, J. W. Richards and J. Crawford, p. 1289.

[b] Crawford, J., Discussion of paper by R. M. Keeney on "Pig steel from ore
Am. Inst. Min. Eng., June, 1914, p. 1289.

[c] Iron and Coal Trades Review, 1913.

Tipted at Nor-
ielting of copper
, Stephan, and the
er cent copper and
ferent electrothermic processes
Canada, Department of Inter-

furnace of the shaft type, the electric iron reduction shaft furnace is necessarily limited to the use of charcoal. Hence it is necessary that such a furnace be located in close proximity to a well-timbered region, where charcoal as well as electric power can be produced at a low cost.

POSSIBLE USE OF CRUDE OIL AS A REDUCING AGENT.

In southern California and in other Western States there are rather large iron deposits of high-grade ore but coke is too expensive to permit ordinary blast-furnace smelting and the use of charcoal for electric-furnace work is entirely out of the question, as there are no forests to furnish the wood necessary for its production. On the other hand, crude oil is generally rather plentiful and comparatively cheap in such districts, especially in California.

Aside from the possible use of oil in connection with electric-furnace work, those interested in the subject have for years been considering the possibility of using crude oil as a reducing agent. So far as the authors know, the oil has not as yet been so used successfully. That the carbon and the hydrogen of the oil will reduce iron oxides is self-evident, but as yet no one seems to have been able to solve the problem of bringing the ore and the oil together at the proper temperature. As a result of a preliminary investigation conducted by the Bureau of Mines as to the possibility of using crude oil as a reducing agent, it seems as if about the only manner in which crude oil may be used for this purpose is first to convert it into a fixed gas and then to introduce this into the crucible of an electric furnace, thus preheating the gas to such a temperature that it will effectively reduce the iron oxides as it passes up through the shaft of the furnace. Be that as it may, it is to be sincerely hoped that ultimately a suitable process may be devised whereby oil may be used as a reducing agent, and thus broaden the field for the possible application of the electric furnace in the reduction of iron ores.

USE OF ELECTRIC IRON REDUCTION FURNACE AT PRESENT.

That the electric furnace has been successful in the smelting of iron ores in districts where the conditions are favorable is shown by the fact that 10 furnaces of the Swedish type with a total capacity of about 22,000 kilowatts have been erected in Sweden, Norway, and Switzerland. In this country there is one iron plant of two electric furnaces with a total capacity of 5,000 kilowatts in operation at Heroult, Cal. The type of furnace used in California is different from that used in Sweden, owing to the fact that a different grade of iron is desired from that produced in Sweden; that is, in Sweden a metal is produced that is low in silicon and carbon and particularly well suited to steel making, whereas in California the demand is for a soft gray foundry iron.

As to the advantages of the metal produced in a Swedish type of furnace for steel making, they have been stated by Keeney[a] to be as follows:

1. That it can be converted into steel with greater facility and at a lower cost.
2. That it admits of greater economy in power consumption.
3. That it admits of greater economy in reducing material.
4. That the carbon content can be controlled within a limit of 2.20 per cent maximum.
5. That the losses of iron in the slag will not exceed reasonable limits, say 6 per cent FeO.

A metal has been made by the Noble Electric Steel Co., "quite similar in both appearance and analysis to the pig iron which was at that time reported as being used successfully for steel making in Sweden," concerning the use of which Crawford[b] reports as follows:

> Stimulated by the results which were being obtained in Sweden we made considerable effort to induce steel makers on the Pacific coast to try it. Finally by making a very attractive price we induced one firm to use it. This concern operates both basic and acid open-hearths for making concrete reinforcing steel. The report of the works superintendent on it was rather indefinite but not enthusiastic. He said "It worked pretty well, but normal pig iron was more satisfactory." Since that time we have sold this concern about 1,000 tons of normal low-silicon pig iron and also a few odd carloads of white iron which approached in analysis pig steel. They advise that no difference is noted in the working of normal electric-furnace pig iron as compared to normal blast-furnace iron of similar analysis. The pig iron brought the market price, but the pig steel always had to be offered on more favorable terms, and even at a reduced price it did not call forth any repeat orders.
>
> These remarks are not intended to be construed as a contradiction of the favorable reception which pig steel has been accorded by the Swedish steel men, but it does seem to indicate that to gain the advantages claimed pig steel must be used "according to prescription" and a good deal of "missionary work" might be necessary before American steel makers, who have no patriotic interest in the matter, would do the necessary experimenting to prove the advantages claimed.

ENGINEERS' REPORT OF THE EXPERIMENTAL WORK AT TROLLHÄTTAN.

The engineers in charge of the experimental work at Trollhättan made the following statements in their final report according to the Iron and Coal Trades Review:[c]

QUALITY OF PIG IRON PRODUCED IN ELECTRIC FURNACE.

> The silicon content does not vary more than in an ordinary blast furnace. The phosphorus content is lower than with the same quality of charge in an ordinary blast furnace; this is due to the lower consumption of charcoal. The percentage of sulphur is, however, slightly higher in the electric furnace. But it should be observed that both at Trollhättan and at Hagfors unroasted ores have been used without any difficulty arising from the sulphur present.

---

[a] Keeney, R. M., Pig steel from ore in the electric furnace: Bull. Am. Inst. Min. Eng., February, 1914, pp. 349–367. Discussion, Ibid, J. W. Richards and J. Crawford, p. 1289.

[b] Crawford, J., Discussion of paper by R. M. Keeney on "Pig steel from ore in the electric furnace:" Bull. Am. Inst. Min. Eng., June, 1914, p. 1289.

[c] Iron and Coal Trades Review, 1913.

furnace of the shaft type, the electric iron reduction shaft furnace is necessarily limited to the use of charcoal. Hence it is necessary that such a furnace be located in close proximity to a well-timbered region, where charcoal as well as electric power can be produced at a low cost.

POSSIBLE USE OF CRUDE OIL AS A REDUCING AGENT.

In southern California and in other Western States there are rather large iron deposits of high-grade ore but coke is too expensive to permit ordinary blast-furnace smelting and the use of charcoal for electric-furnace work is entirely out of the question, as there are no forests to furnish the wood necessary for its production. On the other hand, crude oil is generally rather plentiful and comparatively cheap in such districts, especially in California.

Aside from the possible use of oil in connection with electric-furnace work, those interested in the subject have for years been considering the possibility of using crude oil as a reducing agent. So far as the authors know, the oil has not as yet been so used successfully. That the carbon and the hydrogen of the oil will reduce iron oxides is self-evident, but as yet no one seems to have been able to solve the problem of bringing the ore and the oil together at the proper temperature. As a result of a preliminary investigation conducted by the Bureau of Mines as to the possibility of using crude oil as a reducing agent, it seems as if about the only manner in which crude oil may be used for this purpose is first to convert it into a fixed gas and then to introduce this into the crucible of an electric furnace, thus preheating the gas to such a temperature that it will effectively reduce the iron oxides as it passes up through the shaft of the furnace. Be that as it may, it is to be sincerely hoped that ultimately a suitable process may be devised whereby oil may be used as a reducing agent, and thus broaden the field for the possible application of the electric furnace in the reduction of iron ores.

USE OF ELECTRIC IRON REDUCTION FURNACE AT PRESENT.

That the electric furnace has been successful in the smelting of iron ores in districts where the conditions are favorable is shown by the fact that 10 furnaces of the Swedish type with a total capacity of about 22,000 kilowatts have been erected in Sweden, Norway, and Switzerland. In this country there is one iron plant of two electric furnaces with a total capacity of 5,000 kilowatts in operation at Heroult, Cal. The type of furnace used in California is different from that used in Sweden, owing to the fact that a different grade of iron is desired from that produced in Sweden; that is, in Sweden a metal is produced that is low in silicon and carbon and particularly well suited to steel making, whereas in California the demand is for a soft gray foundry iron.

As to the advantages of the metal produced in a Swedish type of furnace for steel making, they have been stated by Keeney[a] to be as follows:

1. That it can be converted into steel with greater facility and at a lower cost.
2. That it admits of greater economy in power consumption.
3. That it admits of greater economy in reducing material.
4. That the carbon content can be controlled within a limit of 2.20 per cent maximum.
5. That the losses of iron in the slag will not exceed reasonable limits, say 6 per cent FeO.

A metal has been made by the Noble Electric Steel Co., "quite similar in both appearance and analysis to the pig iron which was at that time reported as being used successfully for steel making in Sweden," concerning the use of which Crawford[b] reports as follows:

> Stimulated by the results which were being obtained in Sweden we made considerable effort to induce steel makers on the Pacific coast to try it. Finally by making a very attractive price we induced one firm to use it. This concern operates both basic and acid open-hearths for making concrete reinforcing steel. The report of the works superintendent on it was rather indefinite but not enthusiastic. He said "It worked pretty well, but normal pig iron was more satisfactory." Since that time we have sold this concern about 1,000 tons of normal low-silicon pig iron and also a few odd carloads of white iron which approached in analysis pig steel. They advise that no difference is noted in the working of normal electric-furnace pig iron as compared to normal blast-furnace iron of similar analysis. The pig iron brought the market price, but the pig steel always had to be offered on more favorable terms, and even at a reduced price it did not call forth any repeat orders.
>
> These remarks are not intended to be construed as a contradiction of the favorable reception which pig steel has been accorded by the Swedish steel men, but it does seem to indicate that to gain the advantages claimed pig steel must be used "according to prescription" and a good deal of "missionary work" might be necessary before American steel makers, who have no patriotic interest in the matter, would do the necessary experimenting to prove the advantages claimed.

ENGINEERS' REPORT OF THE EXPERIMENTAL WORK AT TROLLHÄTTAN.

The engineers in charge of the experimental work at Trollhättan made the following statements in their final report according to the Iron and Coal Trades Review:[c]

QUALITY OF PIG IRON PRODUCED IN ELECTRIC FURNACE.

The silicon content does not vary more than in an ordinary blast furnace. The phosphorus content is lower than with the same quality of charge in an ordinary blast furnace; this is due to the lower consumption of charcoal. The percentage of sulphur is, however, slightly higher in the electric furnace. But it should be observed that both at Trollhättan and at Hagfors unroasted ores have been used without any difficulty arising from the sulphur present.

---

[a] Keeney, R. M., Pig steel from ore in the electric furnace: Bull. Am. Inst. Min. Eng., February, 1914, pp. 349-367. Discussion, Ibid, J. W. Richards and J. Crawford, p. 1289.

[b] Crawford, J., Discussion of paper by R. M. Keeney on "Pig steel from ore in the electric furnace:" Bull. Am. Inst. Min. Eng., June, 1914, p. 1289.

[c] Iron and Coal Trades Review, 1913.

furnace of the shaft type, the electric iron reduction shaft furnace is necessarily limited to the use of charcoal. Hence it is necessary that such a furnace be located in close proximity to a well-timbered region, where charcoal as well as electric power can be produced at a low cost.

POSSIBLE USE OF CRUDE OIL AS A REDUCING AGENT.

In southern California and in other Western States there are rather large iron deposits of high-grade ore but coke is too expensive to permit ordinary blast-furnace smelting and the use of charcoal for electric-furnace work is entirely out of the question, as there are no forests to furnish the wood necessary for its production. On the other hand, crude oil is generally rather plentiful and comparatively cheap in such districts, especially in California.

Aside from the possible use of oil in connection with electric-furnace work, those interested in the subject have for years been considering the possibility of using crude oil as a reducing agent. So far as the authors know, the oil has not as yet been so used successfully. That the carbon and the hydrogen of the oil will reduce iron oxides is self-evident, but as yet no one seems to have been able to solve the problem of bringing the ore and the oil together at the proper temperature. As a result of a preliminary investigation conducted by the Bureau of Mines as to the possibility of using crude oil as a reducing agent, it seems as if about the only manner in which crude oil may be used for this purpose is first to convert it into a fixed gas and then to introduce this into the crucible of an electric furnace, thus preheating the gas to such a temperature that it will effectively reduce the iron oxides as it passes up through the shaft of the furnace. Be that as it may, it is to be sincerely hoped that ultimately a suitable process may be devised whereby oil may be used as a reducing agent, and thus broaden the field for the possible application of the electric furnace in the reduction of iron ores.

USE OF ELECTRIC IRON REDUCTION FURNACE AT PRESENT.

That the electric furnace has been successful in the smelting of iron ores in districts where the conditions are favorable is shown by the fact that 10 furnaces of the Swedish type with a total capacity of about 22,000 kilowatts have been erected in Sweden, Norway, and Switzerland. In this country there is one iron plant of two electric furnaces with a total capacity of 5,000 kilowatts in operation at Heroult, Cal. The type of furnace used in California is different from that used in Sweden, owing to the fact that a different grade of iron is desired from that produced in Sweden; that is, in Sweden a metal is produced that is low in silicon and carbon and particularly well suited to steel making, whereas in California the demand is for a soft gray foundry iron.

As to the advantages of the metal produced in a Swedish type of furnace for steel making, they have been stated by Keeney[a] to be as follows:

> 1. That it can be converted into steel with greater facility and at a lower cost.
> 2. That it admits of greater economy in power consumption.
> 3. That it admits of greater economy in reducing material.
> 4. That the carbon content can be controlled within a limit of 2.20 per cent maximum.
> 5. That the losses of iron in the slag will not exceed reasonable limits, say 6 per cent FeO.

A metal has been made by the Noble Electric Steel Co., "quite similar in both appearance and analysis to the pig iron which was at that time reported as being used successfully for steel making in Sweden," concerning the use of which Crawford[b] reports as follows:

> Stimulated by the results which were being obtained in Sweden we made considerable effort to induce steel makers on the Pacific coast to try it. Finally by making a very attractive price we induced one firm to use it. This concern operates both basic and acid open-hearths for making concrete reinforcing steel. The report of the works superintendent on it was rather indefinite but not enthusiastic. He said "It worked pretty well, but normal pig iron was more satisfactory." Since that time we have sold this concern about 1,000 tons of normal low-silicon pig iron and also a few odd carloads of white iron which approached in analysis pig steel. They advise that no difference is noted in the working of normal electric-furnace pig iron as compared to normal blast-furnace iron of similar analysis. The pig iron brought the market price, but the pig steel always had to be offered on more favorable terms, and even at a reduced price it did not call forth any repeat orders.
>
> These remarks are not intended to be construed as a contradiction of the favorable reception which pig steel has been accorded by the Swedish steel men, but it does seem to indicate that to gain the advantages claimed pig steel must be used "according to prescription" and a good deal of "missionary work" might be necessary before American steel makers, who have no patriotic interest in the matter, would do the necessary experimenting to prove the advantages claimed.

ENGINEERS' REPORT OF THE EXPERIMENTAL WORK AT TROLLHÄTTAN.

The engineers in charge of the experimental work at Trollhättan made the following statements in their final report according to the Iron and Coal Trades Review:[c]

QUALITY OF PIG IRON PRODUCED IN ELECTRIC FURNACE.

> The silicon content does not vary more than in an ordinary blast furnace. The phosphorus content is lower than with the same quality of charge in an ordinary blast furnace; this is due to the lower consumption of charcoal. The percentage of sulphur is, however, slightly higher in the electric furnace. But it should be observed that both at Trollhättan and at Hagfors unroasted ores have been used without any difficulty arising from the sulphur present.

---

[a] Keeney, R. M., Pig steel from ore in the electric furnace: Bull. Am. Inst. Min. Eng., February, 1914, pp. 349-367. Discussion, Ibid, J. W. Richards and J. Crawford, p. 1289.

[b] Crawford, J., Discussion of paper by R. M. Keeney on "Pig steel from ore in the electric furnace:" Bull. Am. Inst. Min. Eng., June, 1914, p. 1289.

[c] Iron and Coal Trades Review, 1913.

The quality of the electric pig iron has been highly commended. It acts particularly well in the open-hearth furnace, and steel made from it is certainly not inferior to steel made from ordinary pig iron. Mr. E. Odelberg, managing director of the Stromsnas Iron Works, states that the electric pig iron is "of the very best quality for the open-hearth process, and, as regards the uniformity of the silicon content, fully as uniform as iron from an ordinary blast furnace." Mr. A. Herlienus, managing director of the Uddeholm Co., states that "the electric pig iron has been used with satisfactory results, both for the open-hearth, Bessemer, and the Lancashire processes. Generally speaking, there has been no difficulty in obtaining pig iron of uniform quality, although slightly better uniformity may possibly be obtained with a very carefully conducted blast furnace."

It has been found that the proportion of concentrates ought not to exceed 20 per cent of the ore charged. This figure, however, does not appear to be final, as in a later and somewhat modified furnace of the same type at the Hagfors Iron Works 25 per cent of concentrates is used without any difficulty.

The power consumption per ton of pig iron varies in proportion to the iron content in the ore. A poor ore or pig iron high in silicon and manganese requires more power than a rich ore or a pig iron low in silicon and manganese. For such iron the power consumption averages only 2,067 kilowatt-hours per ton of pig iron; that is, there are obtained 4.22 tons of pig iron per kilowatt-year, or 3.10 tons per horsepower-year.

The charcoal consumption per ton of pig iron varies from 20 to 24 hectoliters (56 to 68 bushels), depending on the quality of the charcoal and the charge. Coke has been found to be unsuitable for this furnace unless mixed with charcoal.

The consumption of electrodes at Trollhättan has been reduced to less than 3 kilograms (6.6 pounds) per ton of pig iron. At Hagfors it has amounted to as much as 6 to 9 kilograms (13.2 to 19.8 pounds). This discrepancy is explained by the fact that the electrode consumption is increased in proportion to the higher power consumption for a poorer charge, and is further increased by the more efficient circulation of gases and higher CO^2 content in the gas. The lower electric load per unit of surface at the Hagfors furnaces also contributes to the higher electrode consumption at this plant.

The cost of repairs is lower than there appeared at first to be reason to expect. In the manufacture of pig iron containing silicon and manganese the costs for repairs are higher than in producing pig iron with low contents of those elements.

VALUE OF GAS PRODUCED.

At the plant of the Uddeholm Co., at Hagfors, the gas from the furnaces has been used with good results for heating the open-hearth furnaces. It has been estimated that the value of the gas obtained per ton of pig iron may be taken at 2.50 kroner (about 0.42 cent). We quote from the report a summary of the most important figures relating to the economical results. These show that step by step the results have been improved and the quantity of iron per horsepower-year increased, whereas the electrode consumption and time for repairs have been reduced, these three items in conjunction with the saving in charcoal being the decisive factors as regards electric iron smelting.

figures show that during the last few months as much as 3.20 to 3.10 tons of
obtained per horsepower-year, whereas before the alterations then made
age figure was 2.86 tons. The highest expected yield was 3 tons per
figure that has thus been exceeded. It may also be mentioned
eriods of several weeks while especially suitable ores were used
figures above mentioned have been materially exceeded. It
as regards efficiency the results of the operation of the furnace
ations. The electrode consumption was 13.8 kilograms (30.4
been reduced to about 3 kilograms (6.6 pounds) per ton of
me required for repairs could not be estimated beforehand.

Of
Switzerla
furnaces with
Heroult, Cal.
that used in Swede
desired from that
produced that is low
to steel making, wh
foundry iron.

Experience has shown that both the cost and the time required are less than could have been hoped for. Wherever employment for the gas can be found this should also be taken into account, as is being done at Hagfors, where its value for firing the open-hearth furnaces is estimated to reduce the cost of the pig iron by about 66 cents.

The results of the work done at Trollhättan in reducing iron ores in the electric furnace are summarized in the following table:

Summary of results obtained at Trollhättan.

Item.	Nov. 15, 1910, to May 29, 1911.	Aug. 4, 1911, to June 21, 1912.	Aug. 12 to Sept. 30, 1912.	October to December, 1912.
Ore, concentrates, and briquets, kilograms	4,338,338	7,917,214	1,406,530	2,914,830
Limestone, kilograms	345,405	647,479	108,150	169,944
Charcoal, hectoliters	65,474.5	107,282.5	21,859.5	44,934.5
Coke, kilograms	....	70,854	....	....
Electric energy, kilowatt-hours	6,339,131	10,845,180	1,939,073	3,957,565
Iron content of ore, per cent	60.79	60.75	68.67	65.38
Iron produced, kilograms	2,636,098	4,809,670	965,915	1,005,865
Slag per ton of iron, kilograms	350	324	192	....
Electrodes per ton of iron, gross, kilograms	10.00	6.08	3.02	2.78
Electrodes per ton of iron, net, kilograms	4.95	5.17	3.02	2.78
Charcoal per ton of iron, hectoliters	24.84	22.31	22.63	23.58
Working time, hours and minutes	4,441 20	7,218 23	1,173 8	2,158 30
Time used in making repairs, hours and minutes	236 53	506 7	13 47	49 30
Time used in making repairs, per cent of total time	5.06	6.55	1.16	2.24
Average load, kilowatts	1,427	1,502	1,653	1,833
Time per ton of iron, kilowatt-hours	2.405	2.255	2.007	2.076
Iron per kilowatt-year, tons	3.64	3.88	4.36	4.22
Iron per horsepower-year, tons	2.68	2.86	3.20	3.10

COPPER.

PRESENT STATUS OF THE ELECTRIC SMELTING OF COPPER ORES.

So far as the writers know, the smelting of copper ores in the electric furnace is not done commercially in the United States at the present time. It is reported, however, that in Norway smelting of copper ores with an electric furnace of 750 kilowatts and an estimated capacity of 2,000 tons of ore per annum has been tried at the Ilen Smelting Works, Trondhjem, and it is understood that copper ores are to be smelted regularly at this plant. A consignment of 25 tons of pure copper, the first copper ever produced by electric smelting and refining in Norway, was recently exported from the Bitovaria mine at Kaafjord, near Dyngor. Some months ago it was reported that the electric smelting and refining of nickel and copper would be undertaken by a company at Christiansand.

EXPERIMENTAL WORK OF VATTIER, SCHILOWSKI, WOLKOFF, AND OTHERS.

In addition to the work on a commercial scale attempted at Norwegian plants, experimental work on the electric smelting of copper ores has been done by Vattier, Schilowski, Wolkoff, Stephan, and the writers. Vattier[a] smelted an ore containing 7 per cent copper and

---

[a] Haanel, E., Report of the commission appointed to investigate the different electrothermic processes for the smelting of iron ores and the making of steel in operation in Europe: Canada, Department of Interior, Mines Branch, 1904, p. 215.

8 per cent sulphur with the production of a matte containing 47.9 per cent copper. Schilowski[a] smelted mixtures of raw ore and roasted ore in an electric furnace and produced a matte. He found that the consumption of energy was lowest when the charge contained 60 to 70 per cent of roasted ore. Using an ore containing considerable arsenic, he found it possible to condense the volatilized arsenic in chambers. Wolkoff[b] treated a mixture of copper sulphide (Cu_2S) and copper oxide (CuO) in the electric furnace for the production of copper by the reaction of the sulphide and the oxide. Stephan[c] smelted oxidized copper ores in the electric furnace for the production of metallic copper with charcoal as a reducing agent. In their experimental work the writers have smelted native copper concentrates and sulphide ores of copper in the electric furnace with favorable results.

In view of the results of the experimental work of the writers and others, there seems no good reason why copper-bearing ores can not be as successfully treated in an electric furnace as in a combustion furnace. In all combustion furnaces used for the treatment of copper ores, the fuel takes no part in the reactions necessary for the production of the desired product, unless in the reduction of oxide ores smelted alone, that is, without a mixture of sulphides, a step that is practically unknown in this country at present. For example, in the reverberatory furnace the fuel acts only as the heating agent; in ordinary blast-furnace smelting, the coke is used to supply the heat necessary to raise the temperature so as to permit the necessary reactions between the oxides, sulphates, and sulphides of the charge, and to scorify the resultant mass, separation of the slag and the matte being thus permitted. In partial pyritic and in pyritic smelting the necessary oxidation of the sulphides and iron is produced by the oxygen of the air entering at the tuyères, and the coke used is simply for supplying the amount of heat necessary for carrying out the process, which is not supplied by the oxidation of the sulphur and the iron present in the charge at the time it passes through the tuyère zone of the furnace. Such being the case, there seems to be no reason why the smelting of copper ores could not be done just as well by electric heat as by that derived from the combustion of coke, especially if warranted by local conditions.

SUMMARY.

Briefly, then, the electric smelting of copper ores is nothing more than the substitution of electric heat for the heat derived from the combustion of carbon as produced in blast-furnace smelting. In some cases the reactions of copper smelting would take place to better advantage in the neutral atmosphere of the electric furnace than in the reducing or partly reducing atmosphere of the combustion furnace. Therefore as to whether the electric furnace should be used for the smelting of copper ores will largely depend on the relative cost of coke and electric power. As the use of the electric furnace is not advocated as a competitor of the combustion furnace, but as a substitute for it in those localities where it is not advisable because of the high cost of fuel to use a combustion furnace, there is no apparent reason why the electric furnace may not be developed as a substitute, especially in the treatment of copper-bearing ores. In this connection it is to be remembered that the reason why the electric furnace was developed in the iron industry for the reduction of iron from its ores was one of necessity. As a matter of fact the field for the electric furnace in the reduction of iron from its ores is limited. Perhaps the same is true as regards the possible application of the electric furnace to the treatment of copper ores, but, judging from the comparative costs, it seems that the chances in favor of the electric furnace for the treatment of copper ores are greater than those for its use in the treatment of iron ores, because there is not so great a difference in the cost of coke and electric power in the copper-mining districts as in the iron-smelting centers. Also the cost of electric power is constantly becoming less, owing to improvements in gas engines and steam turbines, so that in districts where water power is not plentiful, but cheap fuels unsuitable for coke making are available, it may be more advantageous to use electric heat than the heat derived from the combustion of coke.

---

[a] Schilowski, J., La fusion electrique de cuivre et des produits intermediares de fonderies de cuivre: Revue de Métallurgie, vol. 9, 1912, p. 205.

[b] Wolkoff, W., Electric smelting of copper sulphide ore: Metallurgie, vol. 7, 1910, p. 99.

[c] Stephan, M., Einiges über die Erzeugung von Metallen im elektrischen Ofen: Metall und Erz, vol. 1, 13, p. 11; Met. and Chem. Eng., vol. 2, 1913, p. 22.

LEAD ORES AND COMPLEX SULPHIDE ORES.

The smelting of straight lead ores in the electric furnace has seemingly never been attempted either commercially or on a large experimental scale, largely because of the ease and cheapness of smelting such ores by combustion processes. For the smelting of ordinary lead ores it has no especial application, but in the treatment of complex sulphide ores the electric furnace might be profitably used.

As stated elsewhere in this report, ores of lead, zinc, and silver are being electrically smelted at Trolhättan. During the smelting the lead collects in the bottom of the furnace and acts as a collecting agent for the silver; the zinc is volatilized and is subsequently condensed. In mining districts of the Western States are complex ores of lead, zinc, copper, gold, and silver that might be profitably treated in this manner, except that if copper were present the process would be further complicated by the formation of a matte. With the solution of the zinc-condensation problem in electric-furnace work, it is not unreasonable to suppose that such complex ores can be electrically smelted with a fair recovery of the base metals, and with a high recovery of the precious metals. Also, owing to the fact that practically as high a temperature as may be desired may be obtained in the electric furnace, it would be possible to smelt complex ores that are high in gold and silver content but low in base metals, such as lead and zinc. Such recovery would be worth the additional expense of wet concentration. In the blast furnace 10 per cent of zinc in the charge causes sticky slags, and a much higher percentage makes the operation of the furnace irregular and difficult. Such slags can be fused readily in an electric furnace. If the ore contained copper and zinc, the ore could be charged into an electric blast furnace, matte being used as an agent for collecting the gold and silver.

GOLD AND SILVER ORES.

In the smelting of gold and silver ores carrying no lead or copper to form either a lead bullion or a copper matte, but containing iron sulphide, the electric furnace might be used in connection with an air blast for oxidation of the iron sulphide, an iron matte being used as a collecting agent for the gold and silver. The value of iron matte as a collecting agent is still largely a matter of personal opinion, but from the pyritic smelting done with iron as a collecting agent and from some of the writers' experiments in which iron matte was used in the electric furnace, it is evident that a fair recovery can be made in this way. As in electric copper smelting, the electric-furnace treatment of these ores is still in the experimental stage.

Recently a plant has been installed at Lluvia de Oro, Chihuahua, Mexico, for the electric melting of zinc cyanide precipitate and the smelting of ore concentrates.[a] The gold-silver bullion resulting is shipped and the slag resmelted or concentrated. The process appears to be successful in this application.

The writers believe that at many mines in isolated districts where fuel is usually high and where hydroelectric power is used for the mine or mill, the cyanide precipitates could be melted more economically in electric furnaces than in combustion furnaces. The construction of a small furnace of the Siemens type is simple and inexpensive. By using the electric furnace when one of the units of the mill is idle for repairs or during the mine shift when little hoisting or drilling is being done, no additional electrical installation would be necessary. Thus, power that under ordinary conditions is wasted will be utilized.

---

[a] Coulslin, H. R., Electric furnace at Lluvia de Oro: Eng. and Min. Jour., vol. 93, 1912, p. 1189.

ZINC.

In the metallurgy of nonferrous metals the electric furnace has had a greater application for the treatment of zinc ores than in the metallurgy of any of the other nonferrous metals except aluminum. Since 1885, when an electric furnace for the treatment of zinc ores was patented by the Cowles brothers, experimental work has been done. However, the process has not been applied to any great extent because of the difficulty of condensing the zinc vapor produced in smelting in the electric furnace. The cause of this difficulty has not yet been definitely determined. With few exceptions the work has not been done on a very large scale, and so it may be said that the electric smelting of zinc ores is still in the experimental stage.

Undoubtedly there is an inviting field for the electric furnace in the metallurgy of zinc, but before its wide application can be expected the condensation problem and various mechanical problems must be solved. The latter should not prove difficult. The special field for electric-furnace work in zinc metallurgy is due largely to the low thermal efficiency of the present zinc retort, which is given by Richards [a] as only 7 per cent.

As the efficiency of the electric furnace is 50 to 75 per cent, the difference in the heat necessary for carrying out the smelting operation is so great as to permit a higher cost of electrical energy than is permissible in many electrometallurgical operations.

In this report the writers discuss broadly and briefly the present methods of retort smelting, experimental work on the electric smelting of zinc ores, and the present status of electric zinc smelting. The Bureau of Mines is investigating the electrometallurgy of zinc ores, and the results of experimental work, together with a complete résumé of literature on the subject, will be presented at a later date.

PRESENT METHODS OF ZINC SMELTING.

Briefly, the present method of zinc smelting consists of the roasting of sphalerite (ZnS) to zinc oxide (ZnO). The roasted ore is then smelted with excess carbon as a reducing agent in a closed fire-clay retort having a condenser attached. The zinc oxide is reduced to zinc at a temperature of 1,033° C. and as the boiling point of zinc, according to various authorities, is from 920° to 930° C., the reduced zinc passes off as a vapor and is condensed as liquid metal in a condenser. In order to make the reaction more rapid the temperature of the retort is kept at 1,100° to 1,300° C.

Zinc vapor condenses into a liquid mass in the range of temperature from 420° to 860° C. The lower temperature is that of solidification of zinc, and the upper approaches the vaporization point. In practice it is the aim to keep the temperature at 500° C., so that the zinc can be tapped off molten from the retort. If the temperature of the condenser is too low the vapor is too dilute, or if the vapor is diluted with some carbon dioxide instead of carbon monoxide, or with metallic vapors other than zinc, there will be a formation of blue powder, which consists of minute particles of zinc, each particle seemingly covered by a thin coating of zinc oxide. Because of this coating of oxide the powder can not be converted to spelter by simple melting.

---

[a] Richards, J. W., Metallurgical calculations, pt. 1, 1906, p. 80.

The process is intermittent and a retort holds only about 200 pounds of mixture. A charge is smelted, the zinc removed from the condenser, and the residue raked out of the retort. Because of the small scale and intermittent nature of the operation the labor cost is high. Likewise the thermal efficiency is low because of the heat being conducted to the charge through the furnace walls. The retorts are an expensive feature of the process, as at the high temperature necessary they last only about a month.

ZINC SMELTING IN THE ELECTRIC FURNACE.

Processes for the electric smelting of zinc ores are of two general classes—first, reduction of the zinc oxide and its compounds by carbon and carbon monoxide, and, second, decomposition of the sulphide by metallic iron. Examples of the first method are the De Laval and Johnson processes, and of the latter, the Cote-Pierron and Imbert-Thomson-Fitzgerald processes. Reduction of zinc oxide with carbon is based upon the reactions

$$\begin{aligned} ZnO + C &= Zn + CO \\ ZnO + CO &= Zn + CO_2 \\ CO_2 + C &= 2\,CO \end{aligned}$$

The use of iron is according to the reaction

$$ZnS_2 + Fe = Zn + FeS_2$$

In neither of these processes does the electric current perform any function other than heating. As alternating current is supplied to the furnace, there is no electrolysis. As is shown later, the process may be performed in either an arc or a resistance furnace.

One essential difference between the reduction of zinc oxide with carbon in an electric furnace and in the retort is that the retort process is intermittent, whereas the electric process may be continuous. In the electric furnace the charge is added at intervals, as may be necessary, and the slag is tapped or allowed to run continuously from the furnace without disturbing the operation of the process. The reduction by carbon or carbon monoxide occurs as in the retort, except that owing to the rapidity of reduction in the electric furnaces as at present designed the third reaction seemingly does not take place as well in the electric furnace as in the retort, so that the zinc vapor cor tains more carbon dioxide, which has a bad effect on the condensation and results in the production of a large amount of blue powder. Various attempts have been made to obviate this evil, the principal one being the passing of the vapor through incandescent carbon before it enters the condenser.

ELECTRIC ZINC SMELTING AT TROLLHÄTTAN AND SARPSBORG.

The largest plant in commercial operation for the electric smelting of zinc ores is that of the Norse Power & Smelting Syndicate at Trollhättan, Sweden, which also has a smaller works at Sarpsborg, Norway.

EQUIPMENT AT THE TWO PLANTS.

The Trollhättan plant has a furnace house 300 by 52 feet, which contains 11 resistance furnaces, 6 on one side of the building and 5 on the other. There are also two refining furnaces and several arc furnaces. In 1912 it was reported that the new furnace house, then partly erected, was to contain eight furnaces of 600 to 900 kilowatts each. The old furnaces each have a capacity of 270 kilowatts. The total power now being used at the works is 3,000 kilowatts, and with the new installation it will be 7,500 to 10,000 kilowatts.

The Sarpsborg plant has three arc furnaces and four refining furnaces.

For the past six or seven years zinc smelting has been conducted at these works in the De Laval furnace, but part of the product has been the result of refining dross and scrap. It is stated that now ore smelting, in which carbon is used as a reducing agent, is being carried on and that regular shipments of finished zinc were made during the year 1912. The only information available about the works is contained in Harbord's report [a] published in 1911, as everything in regard to the process and the results obtained is kept as secret as possible.

SMELTING PROCESS.

The smelting process consists essentially of two operations, concentration of the zinc to a rich oxide, followed by reduction in another furnace. Oxide ore, flux, and carbon used as reducing materials, are charged into the furnace, where most of the zinc and some of the lead are volatilized and condensed, partly as metal and partly as blue powder and oxide, containing 54 per cent zinc and 20 per cent lead. This is really a concentration process, for the blue powder is subsequently mixed with ore and recharged, when a larger percentage of the metal volatilized is recovered as metal. The remainder of the lead, which carries some silver, is reduced to metal in the smelting hearth and is tapped with the slag. Some lead, zinc, and silver passes into the matte and some into the slag.

---

[a] Harbord, F. W., Zinc smelting at Trollhättan: Eng. and Min. Jour., vol. 93,, 1912, p. 344.

Each furnace is of a modified Siemens type with a shallow hearth and covered with a roof. A carbon block bottom forms one electrode and the other passes vertically through the roof. In some furnaces the ore is charged through the roof, in others at one side of the electrode, whereas others have been designed having a continuous side feed. Three-phase current is transformed from 10,000 volts to 110 volts at the furnaces. The furnaces are connected one to a phase. The capacity of a 270-kilowatt resistance furnace is 2.8 tons of ore per 24 hours. Each furnace holds about 3 tons. A condenser is attached to each furnace.

The charge used by Harbord consisted of 600 pounds of roasted Broken Hill slime, 22 pounds of calamine, and 165 pounds of coke. Broken Hill slime averages 32 per cent zinc, 23 per cent lead, and 25 ounces per ton silver. The powder resulting from this charge was resmelted in another furnace, the charge being 220 pounds of roasted Broken Hill slime, 440 pounds of powder, 55 pounds of coke dust, and 11 pounds of lime. Three furnaces were operated on ore mixture, and four furnaces on ore-powder mixture. At the end of the second day the ore furnaces were making sufficient powder to supply the powder furnaces. The furnace condensers were tapped every four hours for crude zinc and powder, and the slag, matte, and lead were tapped about every eight hours.

RESULTS OF OPERATION OF FURNACES.

During the first part of the run the slags were not clean because of imperfect separation of matte and slag. This fault was caused by the use of too basic a slag and by imperfect mixing of the charge. Toward the end of the work this was improved considerably. There was also considerable trouble experienced in changing electrodes, owing to defective mechanical apparatus, a difficulty that could easily be remedied in a new plant. There were no serious stoppages caused by failure of the furnaces.

In 27.58 days the seven furnaces smelted 578 metric tons of roasted Broken Hill slimes, 19 tons of calamine, and 22.5 tons of blue powder from stock. From this material there was produced 160.8 tons of crude zinc and 36 tons of powder. At the end of the run there was 13.4 tons more powder on hand than at the beginning. The crude metal averaged 79 per cent zinc, 20 per cent lead, and 0.6 per cent iron. From this there was produced on refining 112.4 tons of spelter containing 99.9 per cent zinc and 24.7 tons of lead. The lead tapped with the slag was remelted to remove the slag. This yielded 41 tons of marketable bullion, containing 141 ounces of silver per ton. There was also obtained 17 tons of leak lead, assaying 27 ounces silver per ton. In addition there was 9 tons of skimmings which contained lead, zinc, and silver. The total input of metals was 204.04 tons of zinc, 128.35 tons of lead, and 15,750 ounces of silver. Thus with 537 tons of ore charged the charge averaged 38.1 per cent zinc and 24 per cent lead. The extraction as metals was 130.46 tons of zinc, 94.94 tons of lead, and 7,230 ounces of silver. The yield as metals was then 64 per cent zinc, 73.99 per cent lead, and 45.9 per cent silver. Including the metals in the powder left the yield was 73.4 per cent zinc, 79.3 per cent lead, and 49.5 per cent silver.

At the Sarpsborg plant the electrothermic-refining results on the crude spelter from the powder furnaces were as follows: Fine zinc 83.9 per cent, powder 9.8 per cent (corresponds to 8.8 per cent metals), residues of lead, etc., 2.2 per cent, charge in furnace 1.1 per cent, impregnations in brick walls of furnace and condenser 0.5 per cent, unaccounted for 3.5 per cent, total 100 per cent. The effect of a new lining is shown by the loss unaccounted for, being 5.7 per cent at Trollhättan during the experimental run, as compared with 3.5 per cent in regular running at Sarpsborg.

The consumption of electric current in the experimental run at Trollhättan averaged 2,078 kilowatt-hours per ton of ore smelted, which does not include current used in resmelting the powder. Two tons of powder was retreated per ton of ore smelted. A comparison of the resistance furnaces at Trollhättan with the arc furnaces at Sarpsborg shows that while one was as good as the other for producing the desired reaction, the energy consumption was 70 per cent more in the arc than in the resistance furnace. The consumption of electrodes was also higher in the arc than in the resistance furnace, being 89.2 pounds per ton of ore at Sarpsborg and 69.3 pounds per ton at Trollhättan.

COMMENTS BY HARBORD AND MOULDEN.

Regarding the process, Harbord[a] reports as follows:

> The weak point of the process is the large amount of metallic powder produced in proportion to the metals. The recovery of a large percentage of metals is admittedly a very difficult problem, but that present practice can be very greatly improved upon I have not the least doubt, leading to decreased consumption of energy and reduction of labor costs. One detail which is a great improvement on the early practice is the better separation of the crude zinc from the powder by a mechanical stirrer.

At the time Harbord made his report, J. C. Moulden,[b] who is connected with a company (the Sulphide Corporation) that ships the Broken Hill slimes used at Trollhättan, stated that he was of the opinion that the extraction, after certain improvements should be made, would eventually be 75 per cent zinc, 80 per cent lead, and 80 per cent silver.

The cost of power at Trollhättan is about $10 per kilowatt-year or 0.11 cent per kilowatt-hour.

---

[a] Harbord, F. W., Zinc smelting at Trollhättan: Eng. and Min. Jour., vol. 93, 1912, p. 344.

[b] Met. and Chem. Eng., vol. 9, 1911, p. 673.

EXPERIMENTS AT M'GILL UNIVERSITY.

For several years extensive experimental work on a laboratory scale has been conducted under the direction of Dr. Alfred Stansfield and Mr. W. R. Ingalls.[a] This experimental work has been largely directed toward a study of the condensation problem and the speed of reduction. Uncommonly high percentages of carbon dioxide were found in the gases from the electric furnace, which, as previously stated, prevents condensation of the zinc as metal by oxidizing the condensing globules of the zinc and preventing coagulation. Other experimenters have noted this difficulty, as well as the presence of considerable quantities of carbon and ore dust in the condenser. The latter are believed to be due to the stirring up of dust in feeding the charge into the furnace.

Experiments were also conducted on the reduction of zinc oxide in an intermittently heated retort. The charge was introduced into the retort at the beginning of the operation and at the end the residue was discharged as an unfused residue. Reduction took place slowly and the results obtained showed that although it might have been possible to operate the process continuously, such a course was not feasible. When the furnace was started with a bath of slag and the charge introduced continuously upon the bath, the reduction became relatively rapid. No explanations were given for this increase, but Ingalls states that a retort of small proportions smelts a surprisingly large quantity of charge by comparison with the retort of ordinary practice at an equivalent temperature. With a furnace consisting of a plumbago crucible 12 inches in diameter, 10 pounds of ore per hour was smelted. With a furnace 18 by 18 inches in horizontal section, 737 pounds was smelted in 23 hours. However, the statements as published are not complete. The output of an electric furnace is due chiefly to the energy input and not to the interior volume of the furnace. The capacity in kilowatts of the furnaces used is not given, but it is clear that, in comparison with a combustion retort, the electric furnace has a high output per unit of interior volume.

As the electric furnace may have a high temperature, most of the zinc may be driven off, a low zinc slag being left to be tapped from the furnace. A calcareous slag as well as a high temperature is also necessary. In the experiments at McGill University, the slags contained less than 1 per cent of zinc.

Interesting figures of power consumption were obtained in the experiments at McGill. In one run lasting 24 hours, with a resistance furnace 18 by 18 inches, the power consumption was 1,610 kilowatt-hours per short ton of ore smelted. Theoretically it is estimated that 955 to 1,060 kilowatt-hours per short ton of ore is necessary to smelt ordinary zinc ore. Ingalls concluded that a figure of 1,200 kilowatt-hours per short ton would be ample. He also concluded that there is some chance for electric zinc smelting if such smelting can be done with 1,200 kilowatt-hours per ton of ore, if the labor and electrode costs can be reduced materially, and if 90 per cent of the metals can be extracted.

---

[a] Ingalls, W. R., The electric smelting of zinc ores: Eng. and Min. Jour., vol. 94, 1912, p. 7.

Previous to the experiments of Stansfield and Ingalls, Stansfield and Reynolds conducted experiments on the smelting of lead and zinc sulphide ores carrying silver, with the intention of distilling and condensing the zinc, and reducing the lead in the molten form, thus collecting the silver. The experiments showed the possibility of smelting the ores in the manner indicated, and the extraction of lead was particularly satisfactory. The later work of Stansfield and Ingalls verified the former results and ores of this class are now being treated at Trollhättan.

EXPERIMENTS OF JOHNSON.

One of the most persistent investigators of the electric smelting of zinc ores is W. M. Johnson,[a] who has conducted experiments on a large laboratory scale for several years. His furnace has vertical upper electrodes of carbon and a carbon conducting hearth. The ore is fed through the roof of the smelting chamber. There are several tap holes at different levels. The zinc vapor passes through a flue into an adjacent column of carbon which is heated by the passage of the electric current. During the downward passage of the vapor through the hot carbon, the carbon dioxide is supposed to be reduced to monoxide. The vapor then passes into a condenser, where most of the zinc is condensed as metal and some as blue powder. The furnace is operated continuously. The ore is preheated by gas to 900° C. before entering the electric furnace.

Except for a few statements, the information printed about the work done by Johnson does not clearly show the extent to which he has carried condensation without the formation of blue powder, but the use of a column of hot carbon to reduce the carbon dioxide in the vapor seems to have helped to lower the percentage of blue powder formed.

ELECTRIC SMELTING OF ZINC SULPHIDE ORES WITH IRON AS A DESULPHURIZING AGENT.

The two chief exponents of the use of iron as a desulphurizing agent in the electric smelting of zinc sulphide are the Imbert and Cote-Pierron processes. Imbert tested the reaction, without much success, in the combustion furnace. Thomson and Fitzgerald later designed an electric furnace for its application.

---

[a] Johnson, W. M., Notes on electric zinc smelting: Met. and Chem. Eng., vol. 10, 1912, p. 537.

Although the Imbert-Thomson-Fitzgerald process has been tried experimentally on a seemingly large scale for two years in Upper Silesia, little authoritative information has been issued concerning it. Several types of resistance furnace have been used, all having a resistor of solid carbon.

The Cote-Pierron process[a] uses a furnace of the Siemens type, or one having the two vertical electrodes in series, both types being roofed and connected with a column of electrically heated carbon, through which the vapor passes before going to the condensing chamber.

The same trouble has been experienced in using iron as in using carbon for reduction of the zinc oxide, namely, the proportion of blue powder formed. It seems that iron and iron sulphide are volatilized and that other vapors are given off which dilute the zinc vapor and cause trouble in the condensation of the zinc. Even with the column of carbon of the Cote-Pierron process this trouble continued. Moreover, the Cote-Pierron process does not appear to have developed into the commercial success it was expected to be.

Although it is claimed that the use of iron as a desulphurizing agent in the direct treatment of sulphide ores avoids roasting, it is probable that any saving thus effected is more than offset by the cost of ron. For carrying out the reaction, about 700 pounds of iron is stated to be necessary per ton of 30 per cent zinc ore. At $12 per ton the cost of iron would be about $4 per ton of zinc sulphide ore treated. The cost of roasting a zinc sulphide ore is estimated by Ingalls at $1.25 to $1.75 per ton. It is doubtful whether a regenerative process for recovering the iron from the iron sulphide formed would be successful, or cheap enough to reduce the cost below that of roasting. The zinc sulphide might be sold if a market was near, but it probably would be contaminated by other metals in the ore.

PRESENT STATUS OF ELECTRIC ZINC SMELTING.

Although, as previously stated, more progress has been made to date in the electric smelting of zinc ores than with the electric smelting of any of the nonferrous metals except aluminum and metals forming ferro-alloys, such as silicon, chromium, and tungsten, nevertheless the process is still largely in the experimental stage. There is no plant operating on a commercial scale except the Trollhättan works, which take 7,500 to 10,000 kilowatts. The experimental work continues, but as yet none of it has developed a commercial operation.

It was recently reported that the Sulphide Corporation had constructed, at Cockle Creek, New South Wales, an electric zinc smelting plant, combined with a plant for the manufacture of sulphuric acid and superphosphate. The plant was supposed to be ready for operation in June, 1913, but no later information has been received.

---

[a] Fleurville, E., Electric zinc smelting: Met. and Chem. Eng., vol. 7, 1909, p. 468.

DIFFICULTY OF CONDENSING ZINC VAPOR INTO METAL.

From what has been said concerning the work at Trollhättan and the results of others, it is evident that the difficulty lies almost entirely in the condensation of the zinc vapor into metal rather than with the formation of blue powder under the peculiar conditions of the electric furnace. The electric furnace, mechanically or electrically, presents no great difficulties, because all of the troubles formerly experienced have been solved in the construction of large pig-iron, steel, carbide, and ferro-alloy furnaces. The problem, then, is one of a metallurgical nature and is caused by the different conditions and greater speed of smelting in the electric furnace than in the combustion retort.

THE ELECTRODE PROBLEM.

The opponents of the electric smelting of zinc ores, who as a rule appear to have no knowledge of the great development of the electric furnace itself in the treatment of other ores, often state that although the retort is the weak part of the old system, so is the electrode of the electric method. Judging from large-scale electrometallurgical work on other ores the authors do not believe that in general the electrode is an exceptionally weak part of electric smelting. The electrode problem is no longer serious in iron smelting, and in other electric-furnace work. It is only fair to assume that the designer of an electric zinc smelter should stand on the shoulders of accumulated knowledge and utilize the results of others when the metallurgical problems of electric zinc smelting have been solved.

RETORT AND ELECTRODE CONSUMPTION.

Although it is not the purpose of the writers to enter into a discussion of the relative advantages of processes, it may be of interest to present a few comparative facts regarding retort and electrode consumption.

Ingalls[a] states that during a period of ten years the average life of a Silesian retort was 38 days. One charge was melted per day. The Silesian retort is said to take 200 pounds of ore per charge.[b] Hence a retort treats 7,600 pounds or 3.8 tons of ore. Ingalls[c] also states that a condenser lasts 8 to 12 days, so that about four condensers are necessary for the ore smelted by a single retort. He also states that a seasoned retort is valued at 50 cents and a condenser at

---

[a] Ingalls, W. R., The metallurgy of zinc, p. 545.

[b] Editorial: Eng. and Min. Jour., vol. 94, Dec. 14, 1912, p. 1109.

[c] Ingalls, W. R., op. cit., p. 242.

4 cents. Thus, the cost of a retort and condensers for smelting 3.8 tons of ore is 66 cents, or 17 cents per ton of ore smelted.

At Trollhättan, Sweden, the electrode consumption has been reduced to 6 pounds per ton of pig iron produced. Considering that 2 tons of ore was charged for each ton of pig iron produced, the consumption per ton of ore is 3 pounds. The smelting conditions in electric iron reduction would not tend to be as strongly reducing as in the zinc retort, although the ore in each case would be an oxide. Hence it may be expected that the total consumption of electrodes in a large properly designed zinc furnace will not exceed 3 pounds per ton of ore. There is no longer loss of electrode because of unconsumed ends, as that loss has been entirely overcome by jointing both amorphous-carbon electrodes and graphitized electrodes. This procedure reduces the loss by one-half. In some experiments by the writers on a mixture of sulphide and oxidized copper ores with no carbon in the charge and the charge proportioned so as to contain 15 per cent sulphur, the electrode consumption with air blown into the furnace for partial pyritic smelting was only 2 pounds per ton of ore. However, the furnace was designed so that the charge protected the electrode from the air. Amorphous-carbon electrodes can be obtained at 3 to 4 cents per pound, so that on the basis of a consumption of 3 pounds per ton of ore the electrode cost would be 9 to 12 cents, as compared with a retort cost of 17 cents. These figures seem to show that the retort at the present time is the weaker.

THE FUNDAMENTAL DIFFICULTY.

Then, if the failure of the electric furnace in smelting zinc ores is not due to the electric furnace nor the electrodes, what is the metallurgical condition that causes condensation difficulties and has retarded the commercial application of the process? The difficulty is of course due to a difference in the smelting conditions of the electric furnace as compared with the retort. Both physical and chemical conditions influence the formation of blue powder. Some powder forms under certain conditions of pressure and temperature. Just what these conditions are has not been determined. The problem is one for the physical chemist. The formation of blue powder is due largely to the speed of reduction of zinc oxide in the electric furnace and to the presence of volatile impurities in the charge. Boudouard found that the permissible percentage of carbon dioxide in the zinc retort was low, and that when the limit was exceeded the carbon oxidized the zinc, causing the formation of the blue powder. The vapor of the zinc retort is usually below this limit or not much above it, so that the zinc is condensed chiefly as liquid zinc. But in the electric furnace, the temperature directly beneath the electrode in either the arc or the resistance furnace is so high that the reduction proceeds rapidly and the large amount of carbon dioxide formed does not have a chance to be reduced to monoxide by the hot coal of the charge before entering the condenser. Hence, there is the oxidation of the zinc mentioned. By the use of electrodes of large cross section, it is probable that this concentrated heating could be reduced, so that rather than a high temperature at one place there would be a uniform comparatively low temperature all over the charge. This was found to be the case in the smelting of iron ores both at Heroult, Cal., and Trollhättan. Or the current could possibly be distributed more evenly by flat electrodes of rectangular cross section. The formation of blue powder is also caused by volatilization of silicon which condenses on the zinc either as silicon or silica. For example, in some experiments at the Bureau of Mines laboratory, the condensed fumes from a ferrosilicon furnace contained 67.69 per cent SiO_2, 9.72 per cent Al_2O_3, 4.11 per cent FeO, 0.20 per cent MgO, 1.90 per cent CaO, with the rest carbon. This volatilization of silicon occurs in any electric furnace operated with an arc, as in ferrosilicon manufacture, when there is silica in the charge. At the lower temperature of a resistance furnace it is not so likely to occur.

This problem, although difficult, should be solved in time. When it has been solved and there is no need of resmelting a large proportion of blue powder as at Trollhättan, where 2 tons of blue powder is smelted for each ton of ore treated, it is probable that electric zinc smelting will proceed rapidly. The use of iron as a desulphurizing agent does not seem to have advanced as far as reduction of the oxide with carbon, and it is probable that the latter method will keep its present supremacy. Some work has been done in an electric furnace operated under pressure or vacuum, but only a beginning has been made in this direction.

TIN.

Although rather extensive experiments have been conducted in England on the smelting of tin ores in the electric furnace,[a] the authors know of no place where the electric furnace is being used for that purpose at the present time. Moreover, as only small quantities of tin ore have ever been found in the United States or its possessions, the use of the electric furnace for the smelting of tin ores will not be discussed.

---

[a] Harden, J., Electric tin smelting: Met. and Chem. Eng., vol. 9, 1911, pp. 453–457.

PART III. THE MANUFACTURE OF FERRO-ALLOYS IN THE ELECTRIC FURNACE.

By ROBERT M. KEENEY.

INTRODUCTION.

The subjects presented in this part of the report include an account of the development of the manufacture of ferro-alloys in the electric furnace, descriptions of some types of electric furnaces used in ferro-alloy production, descriptions of several European plants that have been visited by the writer, and information regarding the manufacture and uses of each ferro-alloy.

A ferro-alloy is an alloy of iron so rich in some element other than carbon that the alloy is used primarily as a vehicle for introducing that element into the manufacture of iron and steel. Ferro-alloys are not usefully malleable, and they usually contain more of the alloying element than is desirable in an alloy steel.

Ferro-alloys may be used in the manufacture of iron and steel in two ways. First, the ferro-alloy may be added to the steel for its cleansing and deoxidizing effect with the intention that the alloying element will combine with oxygen or some other impurity in the steel bath and pass either wholly or for the greater part into the slag. Second, the ferro-alloy may be used as a fixed addition, the alloying element staying in whole or for the greater part in the steel, to which it imparts some desirable quality.

The problem encountered in the manufacture of ferro-alloys has been the production of an alloy with a low percentage of carbon, a high percentage of the alloying element, and a low percentage of impurities that might be injurious to steel. The alloy should have a low enough melting point so that it can be used in a steel bath of ordinary temperature. To obtain this feature it has been necessary in some cases to produce an alloy with a high percentage of carbon and a comparatively low percentage of the alloying element. The ferro-alloys with a low percentage of carbon are considerably more expensive than the high-carbon alloys, because of the extra refining necessary, which requires a higher power consumption and increased quantities of expensive ores for deoxidization. It is also essential to produce a ferro-alloy of uniform composition, a difficult feature with some alloys. A ferro-alloy that is not uniform is a source of trouble and expense in the manufacture of alloy steel, because it is not possible to regulate closely the composition of the steel produced. How these points have influenced the development of the manufacture of ferro-alloys is shown in the following discussion.

The most important ferro-alloys in order of their use are ferromanganese, spiegeleisen, ferrosilicon, ferrochrome, silicomanganese, ferrotitanium, silicomanganese-aluminum, ferrotungsten, ferrovanadium, ferronickel, and ferrophosphorus. Other alloys not so widely used but employed by some steel makers are ferrocobalt, ferrosilicon-aluminum, silicocalcium-aluminum, and ferromolybdenum. Other ferro-alloys that have been investigated by the manufacturers but for which no wide use has as yet been found are ferroboron, ferrouranium, and ferrotantalum.

EARLY DEVELOPMENT OF THE MANUFACTURE OF FERRO-ALLOYS.

DEVELOPMENT PREVIOUS TO THE USE OF THE ELECTRIC FURNACE.

Up to the year 1899, when the electric furnace was first used for the manufacture of ferro-alloys, all such alloys were made in the blast furnace or the crucible furnace. Ferromanganese with a high percentage of manganese was first produced at Bonn, Germany, in 1886.[a] This alloy was made in a crucible and contained 70 to 80 per cent manganese. In 1873 the manufacture of ferromanganese was first conducted in the blast furnace, a method by which the greater part is manufactured to-day. In 1875 ferrosilicon containing 10 to 12 per cent silicon was made in the blast furnace. The manufacture of ferrochrome in a commercial way in the blast furnace was started in 1886. Thus up to the year 1890 the only method of manufacture of ferro-alloys was the use of the crucible, the blast furnace, or occasionally the open hearth. In every case carbon in the form of coke or anthracite coal was used as a reducing material.

The production of a ferro-alloy with a low carbon content or a high percentage of the alloying element is limited in the blast furnace by three difficulties—first, the temperature is too low for the reduction of some of the oxides of the alloying metals, so that only alloys of metals reduced at a comparatively low temperature or of low melting point can be made; second, it is difficult to obtain an alloy containing a high percentage of the special metal; and third, it is impossible to produce a ferro-alloy low in carbon because of the great excess of carbon in the charge.

With the crucible, owing to the small scale of operation necessary, the process is necessarily expensive. Owing to the temperature limitation, certain oxides can not be reduced and metals of high melting point can not be melted; it is difficult to obtain an alloy with a high percentage of the special metal; and if a graphite crucible is used, the percentage of carbon tends to be high in the ferro-alloy.

---

[a] Venator, W., Über Eisen Liegierungen und Metall für die Stahl Industrie: Stahl und Eisen, vol. 28, 1908, p. 41; Iron and Coal Trade Rev., vol. 76, 1908, p. 520.

For these reasons, up to 1890 the manufacture of ferro-alloys was mostly confined to the production of ferromanganese of 70 to 80 per cent manganese, ferrosilicon of 10 to 12 per cent silicon, and ferrochrome of 30 to 40 per cent chromium and of 6 to 12 per cent carbon.

INTRODUCTION OF THE ELECTRIC FURNACE.

The opportunity for improvement in the production of high-grade ferro-alloys by the use of the electric furnace was made evident by the researches of Moissan,[a] beginning in 1890, upon the reduction of metallic oxides in the electric furnace. Moissan used an arc furnace, consisting of a chamber of refractory material, into which two horizontal carbon electrodes were introduced.

The commercial production of ferro-alloys in the electric furnace began in 1899, when the Bullier patents for the manufacture of calcium carbide were declared valid in France. There was also an overproduction of calcium carbide, which culminated at the same time. The overproduction rendered it necessary for many established carbide works to seek new uses for their electric power and electric-furnace installations. Those works began the manufacture of ferrosilicon, ferrochrome, and ferromanganese in their old carbide furnaces. At that time the manufacture of ferromanganese in the electric furnace did not prove successful because of the high loss by volatilization, and it was abandoned. The production of high-percentage ferrosilicon, ferrochrome, and other ferro-alloys not easily volatilized was very successful.

By 1902 ferrosilicon containing 25 per cent silicon was being used to a considerable extent instead of the blast-furnace alloy of 10 to 12 per cent silicon. This development was quickly followed by the introduction of ferrosilicon containing 50 per cent, 75 per cent, and 90 per cent silicon. The high-grade ferrochrome of 60 to 70 per cent chromium content and 5 to 8 per cent carbon rapidly replaced the blast-furnace product of 30 to 40 per cent chromium and 6 to 12 per cent carbon. Later the production of ferrochrome containing less than 1 per cent carbon was begun. As the refining possibilities and high temperature available in the electric furnace were more fully appreciated, the production of many ferro-alloys not previously made began. Also in recent years, by careful control of the temperature of the electric furnace, which is possible in the ordinary arc furnace when run as a resistance furnace, it has been found possible to make ferromanganese without an excessive loss of manganese by volatilization.

---

[a] Moissan, H. The electric furnace. Translated by V. Lenher, 1904.

This ferromanganese is usually combined while molten with molten ferrosilicon to produce silicomanganese, or a similar alloy.

There has been comparatively little change in the type of electric furnace used for making ferro-alloys since 1899. In many plants the old carbide furnaces are still in operation, and where the ferro-alloy is simply being produced directly from the ore with carbon as a reducing agent, the furnace is essentially of the old Siemens crucible type, having a conducting hearth of carbon and an upper vertical electrode (fig. 38). There are several modifications, which are described later, but their difference in design is mainly in shape and in the manner of introducing the current. With one or two exceptions, introduced lately, ferro-alloy furnaces are run with open tops, as in the first years of manufacture. There is no shaft, so that most of the reduction is by solid carbon.

PRESENT STATUS OF THE MANUFACTURE OF FERRO-ALLOYS IN THE ELECTRIC FURNACE.

The growth of the ferro-alloy industry in Europe has been rapid since 1899, but comparatively slow in the United States. In Europe there are about 25 plants engaged in the manufacture of ferro-alloys by the electric furnace, as compared with two plants in the United States. In addition to these there are three companies using means other than the electric furnace in the United States, and one electric-furnace ferrosilicon plant in Canada.

There are several reasons why the growth has been slower in America than in Europe. Hydroelectric power is not as cheap here and not so favorably located for the receipt of raw material and the sale of the product. The water-power sites can not be developed so cheaply as many of the foreign sites, where the cost per kilowatt-year varies from $10 to $20, as compared with $20 to $40 in the United States. In Canada power is somewhat cheaper, but much of it is in inaccessible places. Most of the Norwegian and Swedish plants are on tidewater or navigable rivers. French works are within about 200 miles of Marseilles. The use of ferro-alloys in the manufacture of high-class steels did not advance as rapidly in the United States as in Europe. And owing to less favorable natural advantages, electrochemical and electrometallurgical industries in general have not made so rapid progress and growth.

A large proportion of the ferro-alloys used in the United States is imported, as, although there is a duty, local manufacturers are not able to supply the whole demand. About one-half of the ferromanganese and one-half of the ferrosilicon, as well as a large part of the ferrotungsten, used in the United States is imported. More ferrotitanium and ferrovanadium is manufactured here than abroad. The ferrochrome production just about supplies the domestic demand.

In Europe the industry of manufacturing ferro-alloys in the electric furnace is in excellent condition commercially, with the demand for alloys steadily increasing. Because of the race between European countries in the building of large navies, there is a great demand for ferrochrome. In Europe, the sale of ferro-alloys, especially ferrosilicon and ferrochrome, is controlled by a syndicate of the various plants, each plant, according to its capacity, supplying a certain part of the total market demand.

In the United States there is a ferrotitanium manufacturing company at Niagara Falls, N. Y. An electrometallurgical company has one plant at Kanawha Falls, W. Va., where the principal product is ferrochrome, and another at Niagara Falls, N. Y. Other alloys made are ferrosilicon, ferrotungsten, ferrovanadium, ferromolybdenum, and ferrophosphorus. A chemical company at Primos, Pa., manufactures metals and ferro-alloys by chemical methods or in combustion furnaces. Among its products are ferrotungsten, ferrovanadium, tungsten metal, ferromolybdenum, ferrochrome, ferronickel, and ferroboron. Another company manufactures ferrovanadium by the thermit process at Bridgewater, Pa. Another company has a plant for the manufacture of metals and ferro-alloys at Newark, N. J., but imports most of its products from its foreign works. Among its products are ferrotitanium, ferrovanadium, ferromolybdenum, ferrochromium, and chromium.

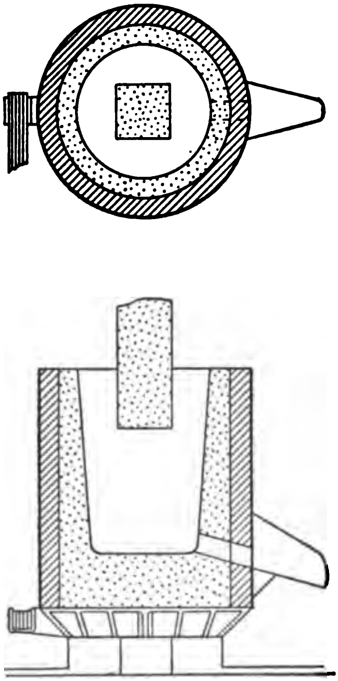


FIGURE 38.—Plan and elevation of Siemens type of ferrosilicon furnace.

TYPES OF ELECTRIC FURNACES USED IN FERRO-ALLOY MANUFACTURE.

FERROSILICON FURNACE OF THE SIEMENS TYPE.

A furnace commonly used in the manufacture of ferrosilicon and other ferro-alloys is of the Siemens type. (Fig. 38.) The furnace is circular in cross section with one upper carbon electrode and a conducting hearth of carbon. The electrodes are held by holders of various types, some of which are shown in figure 39 and in figures 17 to 35. The holders are attached to cables running to hand adjustment wheels. The electrode holders are not usually water cooled.

As yet the use of round electrodes threaded for continuous feeding has not been widespread in ferro-alloy works. In the ferrosilicon furnace it is necessary to line the bottom with carbon paste resting on an iron plate to which the bottom electrical connection is made. The paste of carbon may be surrounded by fire bricks, which are set in a steel shell or are held together by sheet-iron bands. The fire bricks are often not used at all. There is one tap hole. Fire brick can not be used as the interior lining in a ferrosilicon furnace, because it is rapidly attacked by the ferrosilicon. The older furnaces are operated with single-phase alternating current, but the more recent installations are connected to a phase of a three-phase circuit as shown in the lower view of figure 50. These furnaces are built in sizes varying from 200 to 1,000 kilowatts. A 225-kilowatt furnace may have a crucible 2 feet 6 inches in diameter at the top and about 2 feet in diameter at the bottom. The external dimensions are: Diameter, 4 feet; height from base to top, 5 feet; masonry base, about 1 foot 3 inches high. The lining is about 9 inches thick. The furnaces are operated at 50 to 80 volts. A 12-inch square or circular electrode is used. The power factor varies from 0.8 to 0.9.

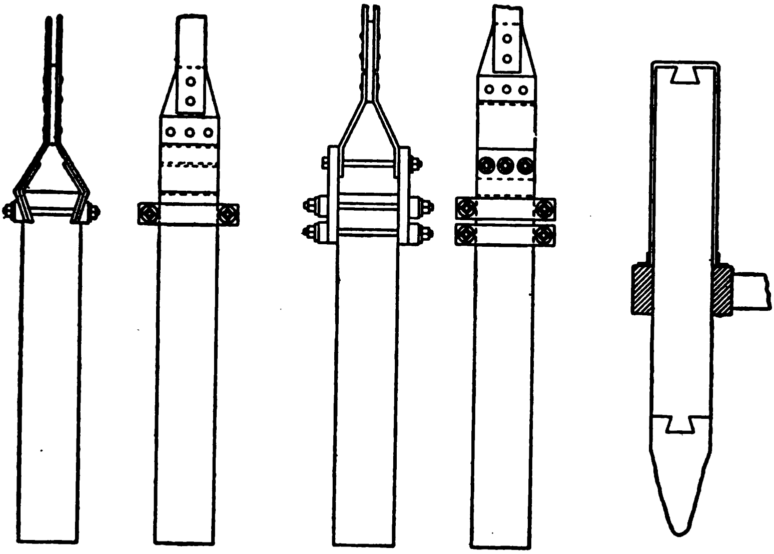


FIGURE 39.—Electrodes and holders used in Siemens type of ferrosilicon furnace.

If a ferrochrome or alloy of medium carbon percentage other than ferrosilicon is to be made in a furnace of this type, the carbon bottom is used, but in the walls the carbon is replaced by a basic lining of magnesite and tar. After a furnace has been operating some time, the material of the charge chills on the walls forming its own lining, and some of the ferro-alloy reduced tends to freeze on the hearth, thus protecting the main part of the molten metal from the carbon. If a ferrochrome containing less than 2 per cent carbon is desired, the lining is of chromite, but this is rather expensive. Ferrosilicon and ferrochrome furnaces of this type have been in continuous operation for periods of two to four years.

Usually the smaller furnaces are charged by a laborer, who shovels the new materials from the floor at the tapping level into the top of the furnace. Larger furnaces have a steel platform around the top for charging from a bin system. In some works the furnaces are set on trucks, so that an old one may be quickly replaced by a new one.

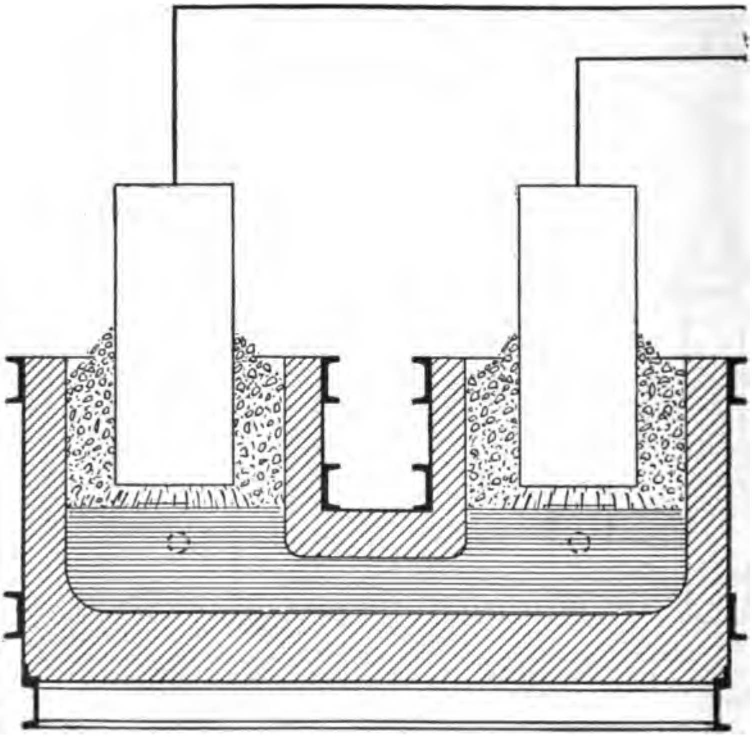


FIGURE 40.—Keller ferro-alloy furnace.

KELLER FURNACE.

The Keller furnace (fig. 40), used for the manufacture of calcium carbide and ferro-alloys, consists of two iron casings of square cross section, forming two shafts that connect with each other at the lower end by means of a lateral canal. There are two vertical carbon electrodes connected in series with the slag and the metal. Ordinarily the current flows through the electrode in one shaft through the charge and through the other electrode, but when the furnace is being started after repairs the connection between the electrodes is made by carbon blocks at the base of each shaft, which are connected by copper bars. There are two tap holes, one in each shaft. The lining used depends on the alloy being made. The electrodes are built of carbon blocks to a total cross section 30 inches square, and are not designed for continuous feeding. They are 4 to 5 feet long. The furnaces are about 14 feet long, 7 feet high, and 6 feet wide. Extra electrodes are kept ready to replace worn ones. Adjustment of electrodes is by hand.

The Keller furnace is built in sizes using 900 to 2,200 kilowatts. Some furnaces are connected as shown in the lower view of figure 50 and others are directly connected to a single-phase system. The furnaces are operated at 50 to 70 volts. The power factor is about 0.7 to 08.

CHAPLET FURNACE.

The Chaplet furnace (fig. 41) for ferro-alloy manufacture has two electrodes in series, one of which is in one chamber, the other being on a channel extending from the main smelting chamber. The current passes through a vertical carbon electrode, through the bath and channel to the other vertical electrode.

The Chaplet furnace has been used by one company especially in the manufacture of low-carbon ferro-alloys. In making low-carbon alloys it is usually operated with a roof when refining, but when reducing directly to a high-carbon alloy the roof is removed. The lining is of dolomite, magnesite or chromite, with a silica-brick roof. The furnace has been built in sizes of 120 to 150 kilowatts.

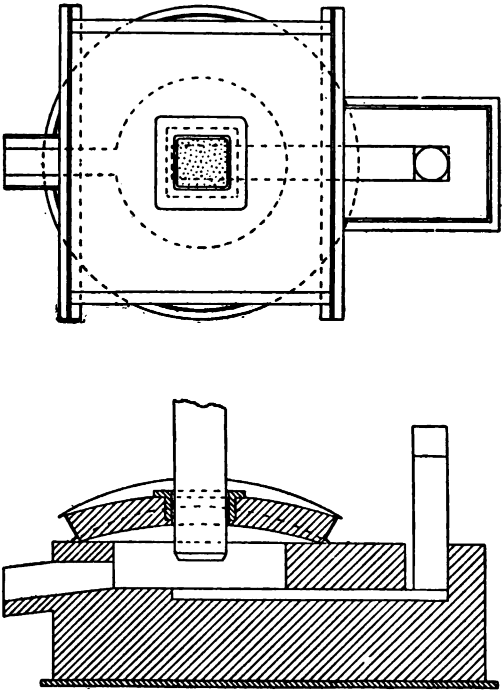


FIGURE 41.—Plan and elevation of Chaplet ferro-alloy furnace.

GIROD RESISTANCE CRUCIBLE FURNACE.

In its early experiment work the Girod Co. devised a crucible furnace in which heating is by resistance. This furnace (fig. 42) consists of a crucible of some refractory material, which is surrounded by a material of high electrical resistance. The use of ferrosilicon for this purpose was patented by Girod. Sometimes coke is mixed with the ferrosilicon to form the resistor. Outside of the resistor are set four carbon blocks, which serve as electrodes and are separated by brick of high insulating qualities to prevent short circuits. The whole is incased in a steel shell and mounted on a framework for tilting by hand. The materials are charged in by hand, and the crucible is covered with a brick cover. Either direct or single-phase current may be used. A general difficulty with a furnace of this type is the prevention of short circuits caused by uneven heating of the crucible, and care must be taken to connect the furnace so that the current takes the longest possible course. The furnace is used for manufacturing ferro-alloys that do not require a temperature above 1,600° C. It is built in sizes up to 150 kilowatts.

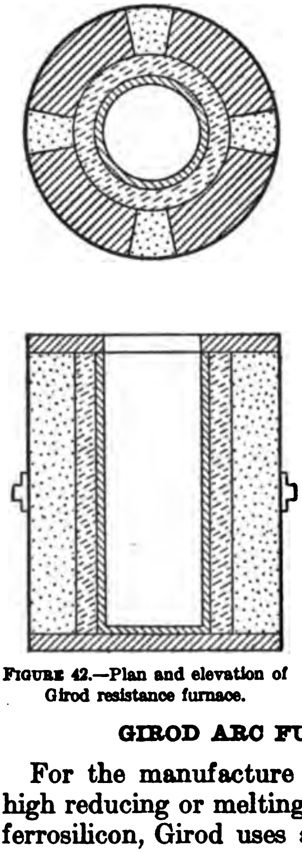


FIGURE 42.—Plan and elevation of Girod resistance furnace.

GIROD ARC FURNACE.

For the manufacture of ferro-alloys of high reducing or melting point, other than ferrosilicon, Girod uses a furnace (fig. 43) of circular cross section, with one or more upper carbon electrodes in parallel and a conducting hearth of dolomite and tar having mild-steel rods embedded or openings into which molten metal is poured and allowed to freeze. These rods are placed radially around the bottom. The ends project outside and are water-cooled where the cables are attached. The lining is usually of dolomite or magnesite throughout, but with the production of low-carbon ferrochrome a chromite lining may be used. Where there are several upper electrodes the diameter of the furnace is greater and the depth about the same as in the single electrode furnace. The general dimensions are about the same as given for the Siemen's furnace, with a conducting hearth of carbon. Either direct or alternating current may be used.

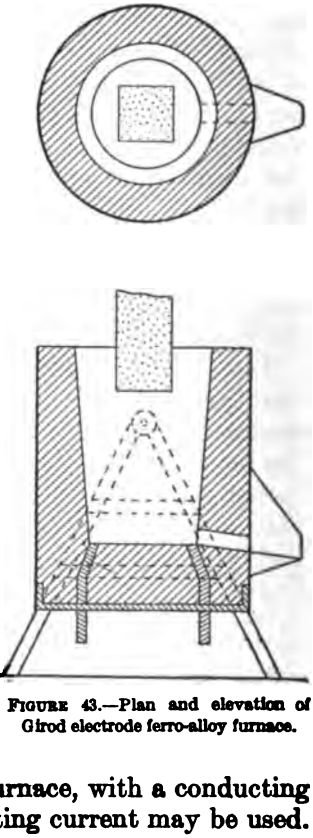


FIGURE 43.—Plan and elevation of Girod electrode ferro-alloy furnace.

MERAKER FURNACE.

At Kopperaaen, near Meraker, Norway, a furnace (fig. 44) similar to the Alby carbide furnace is being used in the production of ferro-alloys, especially ferrochrome. This furnace is rectangular in cross section, with an upper rectangular carbon electrode, and a conducting bottom of carbon, forming the other electrode. The carbon bottom rests on a concrete foundation or the whole furnace may be set on wheels so as to be movable. The lining consists of magnesite and tar, 9 inches thick. The whole is incased in a ⅝-inch steel shell. In one end of the furnace there is a tap hole. At the opposite end connection is made to the bottom electrode. The upper electrode consists of four carbon blocks 10 by 12 inches by 6 feet long, set side by side so as to make an electrode 10 by 48 inches in section.

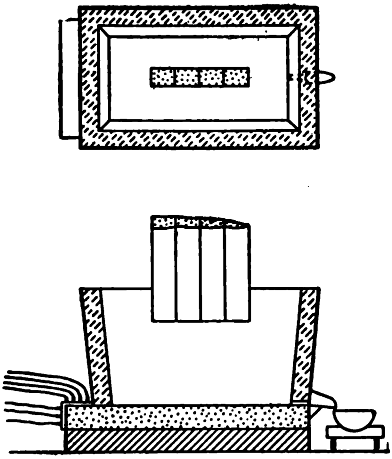


FIGURE 44.—Plan and elevation of ferrochrome furnace at Kopperaaen, Norway.

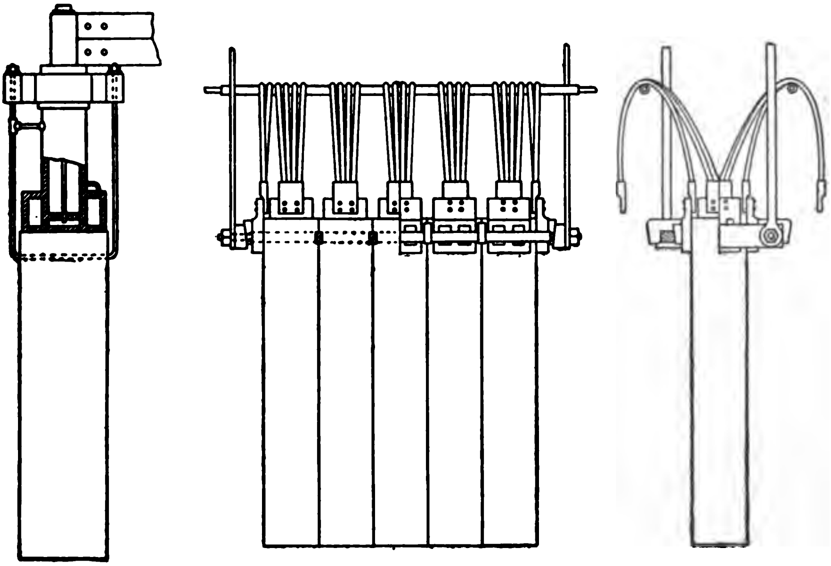


FIGURE 45.—Norwegian and Italian electrodes and holders.

The whole electrode is covered with sheet iron in an endeavor to reduce oxidation and is held by the holder shown in figure 45 (right-hand view), which is supported by cables from above. A spare electrode is left hanging from the framework above the furnace ready to replace one worn out.

A 750-kilowatt furnace is about 10 by 6 feet in section outside at the top and about 9 feet by 5 feet 6 inches at the bottom. The internal depth is about 5 feet. The carbon block at the bottom is 1 foot thick and rests on a concrete foundation 1 foot above the floor. The furnace top is about 7 feet above the floor. These furnaces are operated at 65 volts with either direct or alternating current.

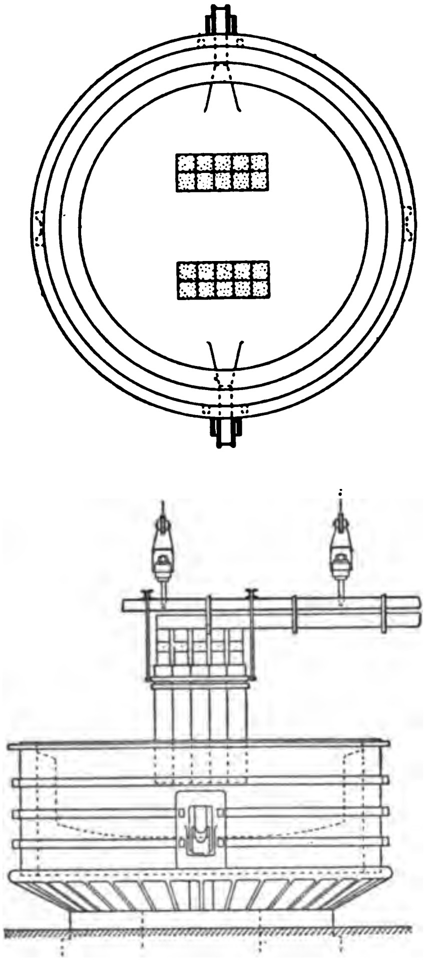


FIGURE 46.—Plan and elevation of single-phase series ferro-alloy furnace.

A furnace of this design with a closed top has been designed at Kopperaaen. This consists chiefly of a steel hood 1½ feet high, lined with fire brick. There is an opening for the electrode, flues for drawing off the gases, and charging doors. Little gas escapes from this furnace except through the flues. The top reduces the electrode consumption considerably.

SERIES FURNACE.

A furnace designed to avoid the use of a conducting hearth and commonly called the "series" furnace, is shown in figure 46. The furnace shown has two vertical carbon electrodes connected in series for operation with single-phase current. If three-phase current is used there are three electrodes connected each to a phase of the system in the delta connection. The construction of the furnace proper is in general the same as for furnaces already described, except that there is no electrical connection with the hearth. Furnaces of this type have been built in sizes up to 3,000 kilowatts.

Three-phase furnaces may be of the shape shown in figure 46, with three electrodes arranged in a triangle and each connected to a phase of a three-phase system. Or the furnace may be rectangular, as shown in figure 47. In neither form is there electrical connection to the bottom. A furnace of this type has been built to take 5,000 kilowatts.

HELFENSTEIN FURNACE.

A furnace recently designed for the manufacture of calcium carbide and ferrosilicon on a large scale is the Helfenstein furnace (fig. 48), which has several shafts set side by side feeding a crucible beneath. Each shaft has its own vertical top electrode, but all are connected electrically by bottom electrodes in the form of a conducting bottom common to all the shafts.[a] There is no other connection between the shafts, so that it is possible to produce different products simultaneously. As shown in figure 48, the shafts enter the crucibles from each side, with the electrodes in the center. The whole furnace is thus rendered air tight. One large 7,500-kilowatt Helfenstein furnace is operating in France and several are being constructed. The use of large units with an air-tight furnace reduces the electrode and the power consumption considerably.

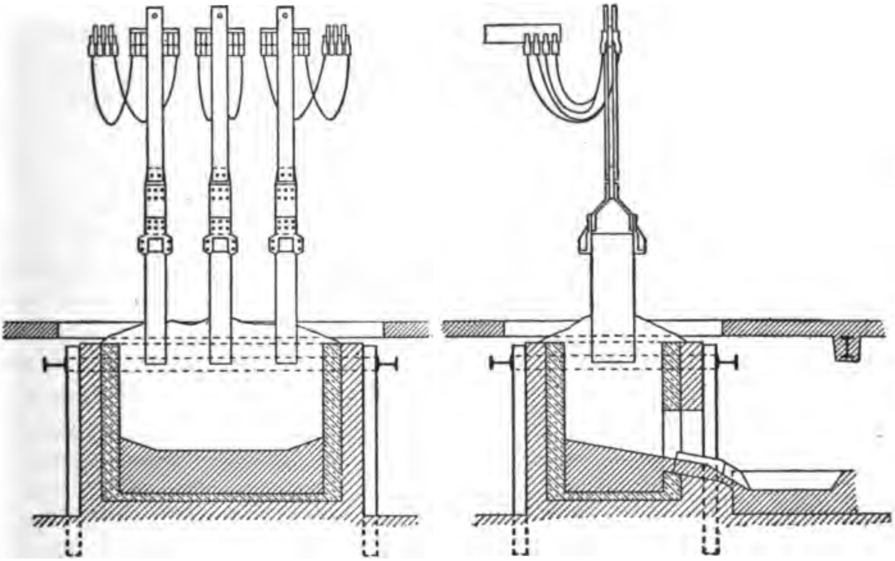


FIGURE 47.—Elevations of three-phase series ferro-alloy furnace.

GENERAL CONSTRUCTION OF ELECTRIC FERRO-ALLOY FURNACES.

FUNDAMENTAL PARTS.

From the types of electric furnaces described it may be seen that in general an electric furnace for ferro-alloy manufacture consists of a crucible without a roof, having either a conducting or nonconduct-

---

[a] Taussig, R., Present status of the development of large electric furnace: Met. and Chem. Eng. vol. 10, 1912, p. 686.

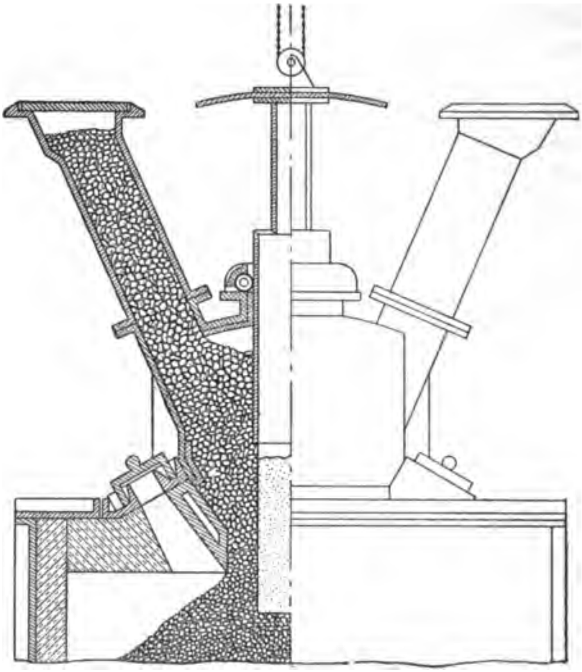


FIGURE 48.—Elevation of Helfenstein furnace.

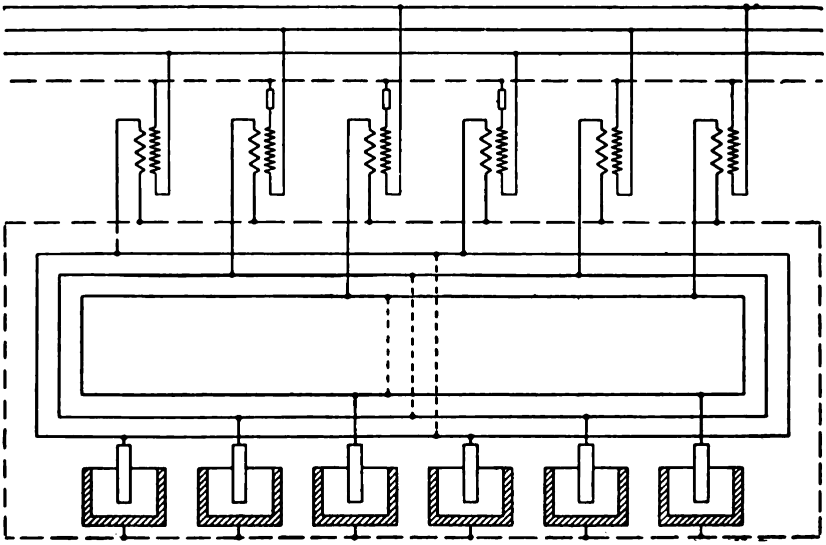


FIGURE 49.—System of electrical connections for several small furnaces.

ing hearth and an upper vertical carbon electrode or electrodes. Most of the furnaces first built had a conducting hearth, and this is still common in furnaces up to about 750 kilowatts, but for larger sizes experience has shown that the nonconducting hearth is preferable. There is a considerable loss of electrical energy by dissipation through the lining, and there is a tendency to have a lower power factor because of the circuit being more completely inclosed in iron. In working a small furnace intermittently—that is, discharging it completely before charging it again—the conducting-hearth furnace is much more easily operated and started when cold. When a large furnace is to be operated continuously for several months at a time on one alloy, this advantage of the conducting hearth is of no importance. A factor little considered in the construction of ferro-alloy furnace is the power factor. Most of the furnaces are completely inclosed in sheet steel, whereas bands would do as well, with much less induction in the circuit.

CONSTRUCTION AND LIFE OF LININGS.

As has been stated, the ferrosilicon furnaces are lined with carbon, and most of the furnaces to be used in producing other alloys with a basic lining of magnesite or dolomite brick or a mixture of tar with either material. When low-carbon ferrochrome is being made, the lining in some furnaces is chromite. Generally a furnace is designed so that the electrode or electrodes are at a sufficient distance from the walls to permit a chilling of the material charged upon the walls. This practice has given the most satisfactory lining. With such an arrangement furnaces have been run two to three years without being relined. The average furnace operating continuously runs about two years before being shut down for repairs. A furnace being operated intermittently must of course be relined oftener.

ELECTRODE HOLDERS.

TYPES.

There are two general types of electrode holders used—first, one with two clamps bolted around the electrode, leaving the top of the electrode exposed; and second, one that grips from above, making it impossible to add a section of electrode from above. The former type has been commonly used in electric steel furnaces, but does not seem to have been so widely used in ferro-alloy manufacture. This is probably because, with the lack until rather recently of an amphorous-carbon electrode threaded for continuous feeding, the most convenient mode of suspension has been by chain with the second type, rather than by a lateral steel frame, as is necessary in the first type. In the future the use of the first type of holder will probably increase because of the possibility of reducing the electrode consumption by using up all butts. A method formerly sometimes used for joining electrodes is shown in figure 39. This connection was not entirely satisfactory and was not widely adopted.

Various designs of the second type are shown in figure 39. Above the point where it grips the electrode the holder is attached to a chain or cable, by means of which it is supported. With a holder of this type about one-third of the electrode is not used. Electrical connection is made by cables attached to the holder.

In figure 45 is shown a type of electrode used in Norway and Sweden for rectangular furnaces. It consists of carbon blocks held together in a framework of steel by wedges, the electrical connections being made by cables attached to the holder itself. The whole is suspended by cables. In figure 45 (left-hand view) is also shown an Italian method, in which the electrical contact is made against the end of the electrode instead of on the sides for the purpose of getting a more even distribution of current throughout the electrode. It is water cooled and the most perfect design technically, but practically is not very widely used.

In many plants, before any of these holders are connected, each electrode is covered with sheet iron to reduce the electrode consumption by oxidation. At some works it is stated that it is doubtful whether this practice results in enough saving to warrant the additional expense. The built-up electrodes are set in a cement of tar and carbon to fill the cracks.

Great care must be taken in building up the electrodes or there will be excessive local heating.

WASTE OF HEAT IN OPEN-TOP FURNACES.

As most of the reduction of oxides in ferro-alloy manufacture is done by solid carbon at a high temperature, most furnaces are run with an open top into which the charge is placed, around the electrode. There results a considerable waste of heat that might be used in preheating the charge. In most of these furnaces the electrode dips about 12 to 15 inches beneath the top of the furnace, which is kept filled with cold material so that the molten mass beneath will not be exposed. There is burning of carbon monoxide around the electrode and an escape of a large volume of gas through the top of the furnace house. As previously mentioned, there has been a seemingly successful attempt made to overcome this waste at Kopperaaen, Norway, with a modification of an existing furnace. The Helfenstein furnace has this objection removed as it is air-tight, and in addition has feeding shafts, where the charge is preheated by the waste gases. In the manufacture of the higher-priced alloys, such as ferrotungsten and ferrovanadium, it is impossible to use any furnace but one with an open top because of the intermittent nature of the operation, but in making ferrosilicon and ferrochrome, it seems advisable to preheat the charge as much as possible.

CHARACTER OF ELECTRIC CURRENT.

A large number of the first ferro-alloy furnaces were supplied with direct current when the furnace house was built adjoining the power house so that there was only about 20 feet between the furnace and the generator. It was soon found that the electrolytic action in a direct-current furnace resulted in deposition of potassium, sodium, calcium, aluminum, and other metals with the alloy so that as pure a product could not be obtained with direct as with alternating current. When alternating current was first used, single-phase current was more common, so that the arrangement remained the same as previously, the generator delivering directly to the furnace at the desired voltage without any transformation.

Later when three-phase current became common, furnaces designed to take single-phase current were connected in groups to three-phase systems by several methods. A method commonly used for the furnace with a conducting hearth and one or more vertical electrodes is shown in figure 49 (p. 114). The primary and secondary are both connected in star connection, with the furnace bottom as the neutral point of the secondary circuit. There are two transformers to a phase, supplying two furnaces. In this system there is apt to be an unbalancing of the load on the three phases. It is used only with small furnaces. To get a better balancing of phases, conducting-hearth furnaces are connected as shown in figure 49, where each furnace is connected to a phase or there may be two furnaces to a phase, the whole system being in delta connection.

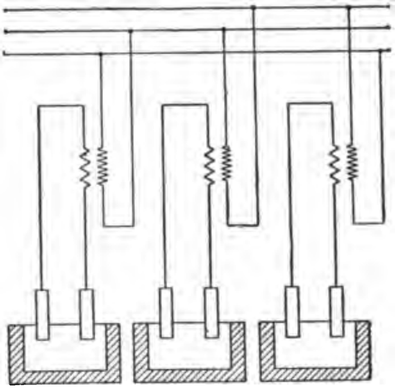


FIGURE 50.—Delta connections of three single-phase furnaces.

For single-phase furnaces the method shown in figure 50 is the best, where three nonconducting bottom furnaces are each connected by the delta arrangement to the three transformers of a three-phase line. Thus the primary and secondary are both connected by the delta system. By this arrangement there is a better balancing of the load in the separate phases. Also it is possible to cut out one furnace if desired.

A three-phase furnace with a nonconducting bottom is connected as in figure 51, where three electrodes are each connected to a transformer, there being a common neutral line between the three transformers. It is not difficult to keep the phases balanced in this system, and it is very satisfactory. If there is more than one electrode to a phase in a furnace of this type it has been found difficult to keep the phases balanced. That has been the experience with one electric pig-iron furnace, whereas with others no difficulty has been experienced.

SOME EUROPEAN ELECTRIC-FURNACE FERRO-ALLOY PLANTS.

KELLER, LELEUX & CO., LIVET, ISÈRE, FRANCE.

The main works of Keller, Leleux & Co. are at Livet, Isère, France, about 20 miles from Grenoble. There is also a small plant using 450 kilowatts at Kerrouse, in the same district. The company originally manufactured only calcium carbide, but later took up ferroalloy production on a large scale in conjunction with the production of carbide. Livet is connected with Grenoble, which is on the main line of the Paris, Lyons & Marseille Railroad, by an electric and steam tramway.

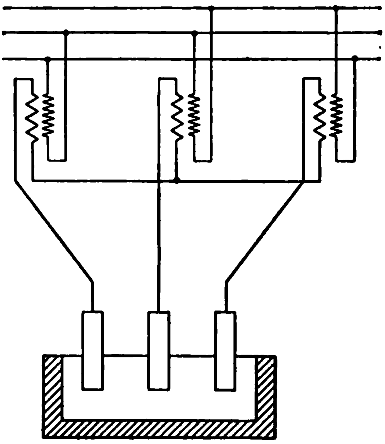


FIGURE 51.—Electrical connections of a three-phase furnace.

POWER SUPPLY.

The company develops its own power on the Romanche River, where a head of 200 feet is utilized by means of a 1½-mile tunnel. The cost of power is said to be $10.66 to $13.33 per kilowatt-year, or 0.12 to 0.15 cent per kilowatt-hour. At high water there is a maximum of 12,000 to 14,000 kilowatts available, but for the four months from November 1 to March 1 this drops to 7,000 kilowatts, some of the furnaces being shut down and others operated with reduced power.

The first installation of generating machinery, which is still in use, consists of six single-phase dynamos of 900 kilowatts each, delivering current of 55 cycles directly to six furnaces at 55 volts. A more recent installation contains three 2,200-kilowatt three-phase machines, connected in parallel and generating current at 2,300 volts and 25 cycles. This is stepped down by transformers at the furnaces. In ddition to the equipment mentioned there are several smaller nerators used for general purposes.

GENERAL PLAN OF THE WORKS AND FURNACES.

The plant is arranged so as to require considerable rehandling of materials to be charged into the furnaces. There are 3 furnace houses of stone-and-steel construction, 35 feet wide, 75 feet long, and about 20 feet high. Each building contains three furnaces, which are set up against one wall with the transformers in a room directly outside the wall. Or, if the furnaces are supplied directly by the generators, the arrangement is the same except that there are no transformers. The space in front of the furnaces is used as a tapping floor. Both carbide and ferro-alloy are tapped into small ladle trucks and dumped in an adjoining shed for cooling and packing. Around the top of each furnace there is a steel floor for charging.

There are six Keller furnaces of the type previously described (fig. 40), working on ferro-alloys and three on calcium carbide. The carbide furnaces take from 1,200 to 2,200 kilowatts each, while the ferro-alloy furnaces are from 900 to 1,000 kilowatts capacity, making a total of about 6,000 kilowatts being used in ferro-alloy production. The furnaces directly connected to the single-phase generators receive current at 50 volts at the furnace. The furnaces on the three-phase circuit have a single-phase transformer to each furnace as shown in figure 50, so that the voltage varies from 50 to 70 volts at the furnace.

PRODUCTS.

Three grades of ferrosilicon, containing 25, 50, and 75 per cent silicon, are manufactured at these works. The charge consists of iron turnings, quartzite, and anthracite coal. Only iron turnings containing less than 0.10 per cent phosphorus are used to obtain the iron. The cost of turnings at Livet is about $14 per ton. The quartzite is ground and contains 94 to 96 per cent SiO_2, with some phosphorus. Sand is not used to supply the silicon at this plant as it appears to cause irregular operation of the furnaces. For a reducing agent, anthracite coal containing 7 per cent ash, 0.013 per cent phosphorus, and 0.41 per cent sulphur is used. The materials are weighed and throughly mixed before being charged. About 500 pounds of 30 per cent alloy is tapped every 2 hours. The 30 per cent ferrosilicon requires 3,500 kilowatt-hours per ton, and the 50 per cent alloy 6,800 kilowatt-hours per ton. After the slag has been tapped into a truck ladle it is skimmed from the metal by means of a green log placed crosswise on a wooden handle. The molds are lined with sand. After having been allowed to cool the ferrosilicon is broken up with a hammer and packed into wooden kegs.

Ferrochrome of all grades is manufactured at Livet. The raw materials used consist of chromite ore containing 35 to 40 per cent chromium, with traces of phosphorus and sulphur, and anthracite coal as a reducing material.

Other ferro-alloys made are silicomanganese, ferrotungsten, ferrotitanium, and ferrovanadium. The total yearly production of the Keller works consists of about 1,500 tons of 25 to 30 per cent ferrosilicon, 3,000 tons of 50 per cent ferrosilicon, 6,000 tons of ferrochrome, 1,500 tons of silicomanganese, 6,000 tons of calcium carbide, and smaller quantities of the higher priced ferro-alloys.

SOCIÉTÉ ÉLECTRO-MÉTALLURGIQUE PROCÉDÉS PAUL GIROD, UGINE, SAVOIE, FRANCE.

In 1898, Girod began the experimental work on the manufacture of ferro-alloys in the electric furnace at Albertville, Savoie, France, with a small 20-kilowatt furnace. In 1899 he opened at Albertville a small works of 38-kilowatt capacity. Later in the same year the erection of a larger plant was begun at that place. The Albertville plant had a capacity of 750 to 950 kilowatts, and consisted of 5 furnaces, each taking 150 to 200 kilowatts. The plant has since been dismantled and the equipment moved to Ugine.

In 1903, the construction of new works was begun at Courtepin, Switzerland. The plant uses 2,250 kilowatts of 25-cycle three-phase current, which is delivered at 32,000 volts and stepped down to 50 to 75 volts at the works. The furnaces at Courtepin are used almost entirely in the production of ferrosilicon containing 25 to 30 per cent, 50 per cent, 75 per cent, and 95 per cent silicon.

In June, 1903, the present company was organized with a capitalization of $360,000, which has been increased to $2,400,000, of which $1,000,000 is in bonds. In 1903 the works at Ugine were erected. In addition to the works mentioned, there is a power plant at St. Gervais, Switzerland.

Ugine is situated on a branch line of the Paris, Lyon & Marseille Railway between Annecy and Albertville. The works are about three-quarters of a mile from the main line, with which connection is made by an electric tramway for freight haulage, which is operated by the Girod Co. The buildings are all on the north bank of the Arly River.

POWER SUPPLY.

The total capacity of all of the Girod power plants is about 28,000 kilowatts. There is a possible development of 30,000 kilowatts more, a total of 58,000 kilowatts. The average cost of power from all sources is about $18.66 per kilowatt-year, or 0.21 cent per kilowatt-hour.

A short distance up the Arly River from the plant is the dam of one of the power plants of the Girod Co. The water is led directly to the plant by a pipe line, the total fall being 416 feet. Ten dynamos, driven by 10 Pelton wheels, generate 6,000 to 7,000 kilowatts of single-phase current, which is conducted directly to the furnaces in the old furnace house.

At La Fayet, also on the Arly River, at a considerable distance from Ugine, 9,000 to 15,000 kilowatts of three-phase current is developed. This is transformed at the works from 45,000 to 50 or 75 volts for the furnaces and 2,500 volts for conversion to direct current. About 4,500 kilowatts of three-phase current is obtained from a plant at St. Gervais, Switzerland, on the Bonnart River. To supply a deficiency during the low-water months, from October 1 to April 1, 6,000 to 7,500 kilowatts, all three-phase at 4,500 volts, is leased from another electrometallurgical company at Veuthin.

The present capacity of the two Girod power plants on the Arly River that supply the Ugine plant is about 24,000 kilowatts. For four months, from October to February, and sometimes to April, the current delivered is reduced to about 12,000 kilowatts when leased power is used. All of the power developed by the Girod plants, except about 6,000 kilowatts that supplies the electric steel works, is used in ferro-alloy manufacture.

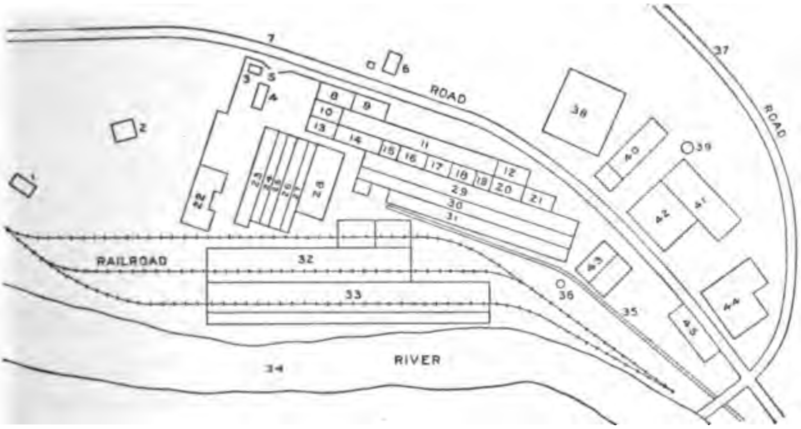


FIGURE 52.—Plan of Girod ferro-alloy plant: 1, garage; 2, villa; 3, porter's lodge; 4, dwelling house; 5, portal; 6, dwelling house; 7, road; 8, fitting and tinsmith shop, 75 by 25 feet; 9, metal-sorting shop, 75 by 25 feet; 10, laborers' dining hall; 11, raw-materials storeroom, 285 by 40 feet; 12, workshop, 60 by 40 feet; 13, dining room; 14, lavatories; 15, foremen's office; 16, packing shop, 60 by 40 feet; 17, hammer with falling weight of 220 pounds; 18, foremen's office; 19, shop for fitting up electrodes; 20, repairing shop; 21, workshop for preparation of graphite; 22, general office; 23, transformer house, 175 by 25 feet; 24, furnace house, 160 by 25 feet; 25, covered yard, 160 by 25 feet; 26, furnace house, 160 by 25 feet; 27, transformer house, 160 by 25 feet; 28, ferro-alloys store house, 130 by 50 feet; 29, covered yard, 440 by 30 feet; 30, old furnace house, 440 by 30 feet; 31, power house, 360 by 40 feet; 32, stock shed, 360 by 50 feet; 33, raw-materials storehouse; new smelting works, 520 by 75 feet; 34, Arly River; 35, conduit pipe; 36, chimney, 125 feet high; 37, road to Ugine; 38, graphite and carbon storehouse, 150 by 100 feet; 39, chimney; 40, electrode storehouse, 170 by 40 feet; 41, furnace house for electrode manufacture, 170 by 40 feet; 42, electrode presses, etc., 110 by 75 feet; 43, sawmill; 44, graphite storehouse; 45, dwelling house.

GENERAL PLAN OF THE WORKS.

The works cover about 500,000 square feet, including the electrode department, which is operated in conjunction with the ferro-alloy plant. The general layout of the plant is shown in figure 52.

The old furnace building is of stone construction, 440 feet long, 30 feet wide, and 18 feet high. The power house runs parallel to it, with a wall between the furnaces and the generators, so that a furnace is not more than 20 feet from its generator. The ends of the furnace building are open, with an open ventilation on the top for the length of the building. Adjoining the furnace building on the side away from the furnaces is an open shed into which the finished products are dumped to cool. Ore, sand, and coal are weighed and mixed on the floor, from which they are shoveled into the furnace tops.

The furnaces in the old works are chiefly used for the manufacture of the higher-priced alloys. There are 18 furnaces, ranging in size from 150 to 560 kilowatts capacity each. Both crucible and electrode furnaces are installed. The furnaces, about 6 feet apart, are set along one wall, with the wheel for hand regulation of electrodes, as well as the electrical instruments, on the opposite wall. The electrodes are suspended by cables running over blocks on the steel trusses of the roof.

At the new works the raw materials are unloaded from the railway cars into the open raw-material shed. An electromagnet crane is used in unloading iron turnings. The ores are then carried in small electrically hauled cars to the new furnace house, where they are elevated to bins above the furnaces. Weighing, mixing, and charging are done here from a floor at the level of the furnace top, considerable labor being thus saved over that necessary at the old plant. The transformers for the three-phase current are set in rooms parallel to each furnace house. The furnaces are set close to the dividing wall. Beyond the other wall of the furnace house is an open shed, into which the hot products are dumped. The furnaces in the new works are all of the electrode type, taking 375 to 900 kilowatts. The electrodes are supported by cables running to the steel framework over the furnaces. Regulation is by hand, as in most ferro-alloy furnaces.

PRODUCTION.

The Girod Co. employs 400 to 500 men in the production of ferro-alloys, the yearly value of which is between $2,000,000 and $3,000,000. The quantity produced varies considerably from year to year, but the production is estimated at 15,000 to 20,000 tons; ferrosilicon, 30 to 90 per cent silicon, 6,000 tons; ferrochrome, 5,000 tons; ferrotungsten, 1,000 tons; silicomanganese, 2,000 tons; other alloys, 1,000 tons. The details of manufacture of these alloys is about as is later described in general under each ferro-alloy.

MERAKER ELECTRIC SMELTING CO.

The works of the Meraker Electric Smelting Co. are at Kopperaaen, Norway, 55 miles east of Trondjhem on the main line of the railroad to Stockholm. The company operates an electric-furnace plant for the manufacture of calcium carbide and ferro-alloys at Kopperaaen, and a pulp-grinding plant about 3 miles west, at Meraker. The concern has been manufacturing since 1905, and, in spite of several fires that almost destroyed the plant, has been very successful. In the summer of 1912, ferrochrome was the only alloy manufactured, but it was the intention of the company to begin the production of other ferro-alloys, especially ferrotitanium, during the next year.

POWER SUPPLY.

The company owns its own power plants. At Kopperaaen there is a fall of 250 feet in the Kopperaaen River. The river is fed by two lakes regulated so as to give a minimum flow of 160 cubic feet per second and a maximum flow of 210 cubic feet per second. At present about 2,250 kilowatts is developed at the foot of this fall at Kopperaaen, and 750 kilowatts more is received from the power plant at the pulp mill in Meraker. The total power used in the electric-furnace plant is about 3,000 kilowatts. At Kopperaaen there are two 1,125-kilowatt direct-current generators delivering current at the furnaces at 65 volts and about 14,250 amperes. There are also several small units for power and lighting purposes. Of the 3,000 kilowatts now being used half is for ferrochrome manufacture and the rest for calcium carbide manufacture. The cost of power is stated to be $8.30 per kilowatt-year, or 0.095 cent per kilowatt-hour. At a point farther up the river 3,000 kilowatts more is to be developed this year, making a total of 6,000 kilowatts used in the electric furnaces. When desired it is possible to develop 4,000 kilowatts more at this point.

GENERAL PLAN OF WORKS AND FURNACES.

Raw materials are unloaded into bins near the Kopperaaen railroad station, about one-half mile from and 300 feet above the plant. There are bins for coal, limestone, and chromite. Besides the bins there is a shipping house where boxes for ferrochrome and iron drums for calcium carbide are made. An aerial tramway runs from the bins and shipping house to the main storage bins about 200 feet from the furnace house but at an elevation 200 feet higher. Here the raw materials are dumped from the tram buckets, and boxes and drums of product are loaded into the buckets after having been hauled up the hill from the furnacehouse by cable skips. At the level there is a kiln for calcination of the limestone. From the bins 200 feet above the furnace house the ores, coal, and lime are lowered to the furnaces by an incline skip discharging into bins above and outside the furnace house.

From these bins the materials are drawn into cars running around a floor in the furnace room about 15 feet above the main working floor, and are dumped into small chutes at each furnace. The chutes, two to each furnace, are about 4 feet deep, and 1½ feet by 1 foot in cross section. From these chutes the ore, coal, and lime are drawn into small cars and dumped into the furnaces about 15 feet away.

The furnace house is about 110 feet long, 75 feet wide, and 22 feet high, and is built of structural steel with brick-and-stone walls. An open ventilator in the roof runs the length of the building. The gases from all the furnaces, except one that is covered and connected with a stack, escape into the furnace room and pass out through the roof.

The main floor of the furnace house is cement, with tracks inlaid for the hauling of small ladle trucks. There is an open space at one end for the dumping of hot carbide and ferrochrome. Around each furnace at the level of the furnace top there is a steel floor, supported by iron pillars. The furnaces are charged from these floors, which are about 15 by 20 feet.

There is a steel floor 10 feet wide suspended above the charging floor. The main bins are discharged into the individual furnace chutes from this floor. This floor also extends out over each furnace to make charging of the electrodes less difficult.

There are five 750-kilowatt furnaces of the Alby type (fig. 44), arranged two on each side and one at the end of the room. Only four of these are operated at a time, one being kept in reserve. There is also a 450-kilowatt furnace of this arc type with a shallow hearth for refining. Three of these furnaces are operated with direct current at 60 volts and one by single-phase current at the same voltage. The electrode holders are of the type shown in figure 45. A spare one is left to facilitate charging at each furnace. Jointed connections for continuous feeding are not used. In the four open-top furnaces an electrode 48 by 10 inches by 6 feet long lasts about 10 days, whereas in the covered-top furnace they last 14 to 16 days. The electrodes project about 10 to 12 inches into the charge, which is not molten at the top, and are consumed down to about 2-foot to 1-foot lengths.

The lining of magnesite and tar in one ferro-alloy furnace had been in use for 22 months and the other 6 months. The power had not been off these furnaces at all during that time except for about 15 minutes a week when electrodes were changed. The current is conducted from the power house at the end of the furnace room by copper cables. The connection to the carbon-block base of each furnace is made by many small wires leading to the main cable line.

PRODUCTS.

The Meraker company produces 4,000 tons of calcium carbide and 2,000 tons of ferrochrome annually. Turkish ore and English anthracite coal are used for the manufacture of the ferrochrome. In calcium-carbide production the power consumption is about 0.375 kilowatt-year per metric ton or 1.5 kilowatt-hours per pound. The power consumption for ferrochrome is 0.75 kilowatt-year per metric ton or 3 kilowatt-hours per pound. The carbide and ferrochrome are tapped every 2 and 4 hours, respectively. The carbide is sized before being packed into 50-kilogram (110-pound) drums, and the ferrochrome is broken into lumps less than 6 inches square and packed into 200-kilogram (440-pound) boxes.

This company makes only ferrochrome that can be produced without the refining process described later, so that the carbon content of its product varies from 2 to 10 per cent. It is very easy to make a ferrochrome of 5 per cent carbon content without refining the product. The cost of manufacture of carbide is given at about $30 per metric ton. All products are sold through a syndicate of manufacturers organized to prevent overproduction if possible. The company employs 120 men, part of whom work an 8-hour shift and part 10 hours. The men in the furnace house are on an 8-hour shift. The minimum wage is $1.25 for a 10-hour shift.

FERRO-ALUMINUM.

Aluminum is usually used by the steel maker in the form of metallic aluminum, but sometimes a ferro-aluminum is made. Metallic aluminum is supplied in half-round sticks or notched ingots. Ferro-aluminum is made containing 5, 10, and 20 per cent aluminum, with the rest iron. The other iron-aluminum alloys, such as ferro-aluminum silicon, are discussed later.

The manufacture of ferro-aluminum consists simply in melting aluminum and iron together in the desired percentages. This may be done in either an electric furnace or a combustion furnace of the crucible type. Aluminum or ferro-aluminum is added in the ladle and serves only for the deoxidizing of the steel.

Iron containing 5 to 6 per cent aluminum is fragile.[a] At 7 per cent aluminum the alloy has a crystalline structure. An iron aluminum alloy containing over 20 per cent aluminum has no magnetism. Ferro-aluminum containing from 0 to 34 per cent aluminum consists of mixed crystal of iron and aluminum.[b] When 34 to 52 per cent aluminum is present there are crystals, and with 52 to 100 per cent aluminum the alloys $FeAl_3$ and Al are found together.

FERROBORON.

Ferroboron is not as yet very commonly used, as the effect of boron on steel has not been extensively investigated. Ferroboron is manufactured directly by the reduction of colemanite $Ca_2B_6O_{11}$, $5H_2O$ and iron with carbon in an electric furnace of one of the types already described. The analysis of a typical Pacific Coast colemanite is as follows:[a]

---

[a] Guillet, L., Étude Industriel des Alliages Métallique, p. 930.

[b] Robin, F., Traité de Métallographie, 1912, p. 304.

	Per cent.
B_2O_3	27.23
CaO	28.80
H_2O	25.30
Fe_2O_3	Trace.
Insoluble	0.74

In the western United States there are large deposits of this mineral, the principal use for which is in the manufacture of borax. In manufacturing ferroboron, carbon is mixed with the colemanite and iron turnings or iron ore in sufficient quantity to produce as complete reduction as possible, although the slags are usually high in boron. The product of the reduction with carbon in the electric furnace is of various grades containing 10 to 12, 20 to 25, and 30 to 35 per cent boron. A typical ferroboron of the latter class had the following composition:

	Per cent.
Boron	32.75
Carbon	2.875
Sulphur	.03
Phosphorus	.005

In a French patent Girod claims that the presence of boron either as colemanite or as the alloy in a charge gives a more fluid slag in the manufacture of other ferro-alloys, and if it goes into the alloy increases its value.

Hansen[b] has patented a method for the production of ferroboron from colemanite with ferrosilicon as a reducing agent. In this way there is no carbon in the ferroboron, but it is apt to contain considerable silicon. The colemanite is powdered and briquetted with enough ferrosilicon to provide silicon for complete reduction of the boron and to slag off the calcium oxide. Water glass or some other suitable material is used as a binder. The briquets are subjected to a temperature of over 2,000° C., giving ferroboron and a calcium silicate slag.

Ferroboron containing about 10 per cent boron seems to give the best results. Ferroboron is added in the ladle and may be used for deoxidizing, desulphurizing, and for a fixed addition of boron to steel.

Guillet[c] states that the best commercial boron steel is that containing 0.22 per cent carbon and 0.5 per cent boron. Boron steels are practically useless unless tempered, when they have high tensile strength and elastic limit and great resistance to shock.

---

[a] Iwai, K., and Ballagh, J. L., Investigation of ferroboron: Min. and Sci. Press, vol. 99, 1909, p. 185.

[b] U. S. Patent 982135, Jan. 17, 1911.

[c] Guillet, L., Étude Industriel des Alliages Métallique, p. 372.

FERROCHROME.

HISTORY.

More ferrochrome is manufactured in the electric furnace than any other ferro-alloy except ferrosilicon. The alloy of iron and chromium, called ferrochromium or ferrochrome, has been known since 1820 through the studies of Faraday and Stodarts, and also by the work of Berthier. Berthier found that by adding ferrochrome containing 17 per cent chromium to steel, so as to give 1½ per cent chromium in the steel, a product of better quality was obtained. Baur found 40 years later that ferrochrome was the best agency to use for adding chromium to steel. Other experimental work on chrome alloys was done by Fremy, Percy, and Mushet.

In 1873 Biermann, of Hanover, announced that his firm was producing ferrochrome commercially. In 1877 the English firm of Hadfield put on the market some ferrochrome containing 10 to 30 per cent chromium. The French firm of Holtzer & Co. also began manufacture. By 1886, as the value of chromium in steel became more understood, there were several regular producers of ferrochrome. In 1899 there began the production of ferrochrome in the electric furnace. Up to that date all of it had been made in either the crucible or the blast furnace.

WORK OF EXPERIMENTERS.

NEUMANN.

Neumann[a] investigated the use of ferrosilicon as a reducing agent for chromite ($FeO.\,Cr_2O_3$) in the electric furnace in an effort to produce a carbon-free alloy. The experiments were performed in an electric furnace holding about 1 kilogram of charge and operating with 100 amperes and 30 to 50 volts. Ferrosilicon containing 91.65 per cent silicon and 1.03 per cent carbon was used as a reducing agent. The chromite contained 31 per cent chromium and 13 per cent iron. A mixture of ($150Al_2O_3 + 100CaO$ or $100Al_2O_3 + 100CaO$) was placed in the furnace, 250 grams being used. When this was fluid, 700 grams of a mixture of chrome ore and ferrosilicon was added. About 140 grams of metal was obtained, which contained 38.05 per cent chromium, 3.09 per cent silicon, and 1.56 per cent carbon. In another experiment the metal contained 43.16 per cent chromium, 2.53 per cent silicon, and 0.87 per cent carbon. There seems to have been a heavy loss through slagging of chromium. From these experiments it is evident that the resulting alloy from reduction with silicon will be high in silicon and also contain considerable carbon if there is any present in the silicon used.

---

[a] Neumann, G., Herstellung von Ferro-liegierung im elektrischen Ofen: Stahl und Eisen, vol. 28, 1908, p. 356.

MOISSAN.

Moissan[a] reduced chromite in the electric furnace with carbon as a reducing agent and obtained a ferrochrome that contained 60.9 per cent chromium, 31.6 per cent iron, 6.1 per cent carbon, and 1.1 per cent silicon. He also conducted experiments on decarburization of ferrochrome. A ferrochrome containing 61.81 per cent chromium, 30.02 per cent iron, 7.53 per cent carbon, and 0.33 per cent slag was broken into pieces and fused under a bath of liquid lime. A fine ground metal was obtained, which contained 64 per cent chromium, 35.12 per cent iron, 0.70 per cent carbon, and 10.22 per cent slag.

EXPERIMENTAL SMELTING OF CHROMITE IN THE ELECTRIC FURNACE.

CONSTRUCTION OF FURNACE USED.

Some experiments were made by the writer[b] in 1912 on the production of ferrochrome from chromite with carbon as a reducing agent. The experiments were performed in a furnace lined with magnesite, having one upper graphite electrode and a conducting hearth of iron rods embedded in magnesite. The interior dimensions of the crucible were: Width 4 inches, length 8 inches, and depth 8 inches. The furnace took 8 to 12 kilowatts of single-phase current at 30 to 50 volts. The furnace held 12 to 15 pounds of the cold charge.

MATERIALS USED IN CHARGE.

The chromite used was a foreign grade used commonly for furnace linings. Analyses of the chromite, coke, lime, and fluorspar used are given below:

Analyses of raw materials used in making ferrochrome.

Chromite.		Coke.		Lime.		Fluorspar.	
Constituent.	Per cent.	Constituent.	Per cent.	Constituent.	Per cent.	Constituent.	Per cent.
Cr_2O_3	[1] 46.35	Fixed carbon	81.48	CaO	92.76	CaF_2	90.00
FeO	[2] 21.45	Volatile combustible matter	.25	SiO_2	1.34	$CaCO_3$	.80
SiO_2	5.48	Ash	17.92	Al_2O_3–Fe_2O_3	1.90	Al_2O_3	8.50
Al_2O_3	12.80	Moisture	.35	MgO	Trace.		
MgO	10.08	FeO	1.20	P	.06		
CaO	Trace.	SiO_2	13.62				
P	.013	CaO	.85				
S	.45	P	.08				
		S	.54				

[1] 31.7 per cent Cr. [2] 16.6 per cent Fe.

---

[a] Moissan, H., The electric furnace, p. 152. Translated by V. Lenher, 1904.

[b] Keeney, R. M., The production of steels and ferro-alloys directly from ore in the electric furnace: Iron and Steel Inst. (Carnegie Scholarship Memoirs), vol. 4, 1912, p. 108.

In these experiments, contrary to the usual European practice in ferrochrome manufacture, lime was used as a flux to show its desulphurizing and dephosphorizing effect with an ore not so pure as the usual ore used in ferrochrome production. In usual practice only the most pure raw materials available are charged, so as to avoid the excess slag caused by adding lime. The only slag formed is from the coal or coke and chromite.

RESULTS OBTAINED.

Five experiments were made in which the furnace was charged and tapped at the completion of reduction. In these experiments the chromium percentage of the alloy seemed to run considerably lower than had been calculated, although this result is explained in a measure by the fact that the carbon in the metal was not considered in calculating the theoretical percentage. The carbon content was high in all of the alloys and does not seem to be influenced by the carbon in the charge as long as there is excess, which was the case. The phosphorus content also was high in all of the products. Seemingly all of the phosphorus charged was concentrated in the metal. This was caused by the excessive reducing conditions which did not permit the slagging of the phosphorus as calcium phosphate. The ore contained considerable sulphur—0.45 per cent—but almost all of it passed into the slag, probably as calcium sulphide. There was considerable loss of chromium and iron in the slag. In some cases the percentage of iron in the slag exceeded that of the chromium, but in no case did the percentage of chromic oxide in the slag exceed 9 per cent, or the percentage of chromium, 4.69 per cent, showing that in the endeavor to keep the carbon in the alloy low the proportion of coke added was not sufficiently in excess for complete reduction or that the furnace was not hot enough. The former was probably the case, as the furnace was operated as an arc furnace throughout the experiments.

In two experiments (Nos. 6 and 7 of table following) the furnace was left full and several tappings were made during the run, the usual practice of ferrochrome manufacture thus being followed. Commercial ferrochrome is usually 5 to 10 per cent carbon, containing 60 to 65 per cent chromium.

Details of the seven experiments mentioned above are presented in the following table:

Details of experiments in the production of ferrochrome directly from ore.

Experiment No.	1	2	3	4	5	6						7		
						a	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*
Charge:														
Chromite ... pounds	10.00	10.00	10.00	10.00	10.00	60.00						40.00		
Coke ... do	1.87	1.87	1.87	1.63	1.36	11.23						8.10		
Lime ... do	1.25	1.25	1.25	1.25	1.25	6.70						4.50		
Fluorspar ... do	.12	.12	.12	.12	.12	.68						.44		
Constituents of alloy product:														
Chromium ... per cent	51.80	48.60	49.70	52.70	57.10	50.69	68.20	58.90	56.10	68.00	67.10	62.60	72.70	68.00
Carbon ... do	10.05	8.74	11.50	3.72	9.28	6.50	9.31	8.72	7.89	4.32	7.40	5.28	8.32	5.43
Silicon ... do	.81	1.10	1.26	.87	.35	.67	.60	1.23	1.25	.96	1.03	.79	.56	.94
Phosphorus ... do	.128	.133	.110	.106	.120	.106	.099	.108	.119	.106	.106	.121	.119	.104
Sulphur ... do	.073	.038	.096	.061	.085	.071	.105	.055	.016	.031	.054	.020	.023	.027
Slag, Cr_2O_3 ... do	8.03	7.57	6.96	8.98	8.81	9.15	12.60	10.72	13.43	13.13	13.34	8.78	11.40	11.35
Slag, SiO_2 ... do	23.40	24.60	23.40	20.25	26.60	32.60	34.20	29.20	28.00	28.90	28.00	36.84	30.50	29.40
Slag, FeO ... do	9.02	7.29	18.96	15.10	10.17	6.10	14.82	15.43	14.81	15.17	17.55	8.73	16.99	18.10
Calculated percentage of chromium	65.50	65.50	65.50	65.50	65.50	65.50						65.50		
Carbon per pound of iron and chromium ... pounds	.312	.312	.312	.271	.228	.312						.418		
Calculated weight ... do	4.45	4.00	4.47	3.87	5.06	29.3						19.4		
Ferrochrome tapped ... do	3.5	4.87	5.15	2.44	2.66	2.66	2.13	3.21	3.21	3.21	3.50	1.50	2.51	7.00
Do. ... per cent	78.5	89.9	96.3	62.95	53.30	[a]61.8						[b]66.8		
Electrode consumption per ton tapped ... pounds	210.00	150.00	142.00	204.00	189.00	48.1						16.3		
Power consumption per pound of alloy tapped, kilowatt-hours	3.18	2.73	2.57	6.38	4.71	3.02						3.53		
Power consumption per ton of alloy tapped, kilowatt-years	.73	.62	.59	1.46	1.08	.69						.81		

[a] Total, 17.92 pounds.

[b] 11.01 pounds.

In these experiments the percentage of chromium in the alloy closely approached the theoretical. The percentage of carbon was also lower in these alloys because of the decarburizing effect of the unreduced oxide in the charge above the molten metal. The slag loss of iron and chromium was higher in these runs than in the intermittent experiments because of unreduced oxide getting into the slag on tapping.

A total of 50 pounds of ferrochrome was tapped during the experiments, or an average extraction of 69.5 per cent. The average iron content of the slag for all experiments was 13.4 per cent FeO (10.4 per cent Fe); the average chromium content of the slag was 10.3 per cent Cr_2O_3 (6.6 per cent Cr). In the intermittent experiments the average percentages in the slag were 12.1 per cent FeO (9.4 per cent Fe) and 8.07 per cent Cr_2O_3 (5.32 per cent Cr). Thus, of the loss of 30.5 per cent of material that was not tapped, 11.9 per cent was chromium and 18.6 per cent was iron, on the assumption that of the total average loss 39 per cent was chromium and 61 per cent iron. A large part of the ferrochrome not tapped stuck in the furnace. Although the average electrode consumption was 158 pounds per ton, the figure obtained in experiment No. 6, 48.1 pounds, would probably be attained in practical operation. The average power consumption was 3.7 kilowatt-hours per pound, or 0.85 kilowatt-year per ton.

The conclusions drawn are, first, ferrochrome can be easily manufactured directly from chromite in the electric furnace; second, the percentage of carbon in ferrochrome can not be kept low by regulating the carbon charged without excessive loss of chromium in the slag; third, the percentage of carbon in the ferrochrome must be regulated by decarburization with an oxide slag of iron or chromite after the slag from reduction has been tapped off; fourth, the proportions of silicon and phosphorus can not be kept low in the alloy under the strong reducing conditions necessary; fifth, sulphur can be easily slagged; sixth, as the addition of lime does not seem to aid in reducing phosphorus, it is advisable to use no lime but raw materials as pure as possible; and, seventh, the power consumption should not exceed 3.7 kilowatt-hours per pound of ferrochrome tapped or 0.85 kilowatt-year per ton.

THEORY OF CHROMITE SMELTING.

REDUCTION WITH CARBON.

In the reduction of chromium from chromite to form ferrochrome with the iron reduced, reduction of chromic acid begins at 1,185° C.[a] Reduction takes place according to the reaction:

$$FeO.Cr_2O_3+4C=Fe.2Cr+4CO$$

---

[a] Greenwood, H. C., Slade, R. E., and Pring, J. N., Reduction of refractory oxides, production of ferro-alloys, and formation of carbides: Trans. Chem. Soc. (England), vol. 93, 1908, p. 1484; Electrochem. and Met. Ind., vol. 7, 1909, p. 119.

A pure chromite ore contains 68 per cent Cr_2O_3 and 32 per cent FeO. For reduction of pure chromite 30 parts of carbon are theoretically necessary for every 100 parts of iron and chromium reduced. In practice this amount is exceeded considerably. In ferrochrome manufacture practically all of the reduction is performed by the solid carbon and not by carbon-monoxide gas. On the basis that the double carbide $Fe_3C.3Cr_3C_2$ forms in reduction with carbon as has been found to be the case, the reduction reaction is as follows:

$$9FeO.9Cr_2O_3+50C=[2(Fe_3C.3Cr_3C_2)+3Fe]+36CO$$

The ferrochrome resulting would contain theoretically 10.4 per cent carbon, 31.4 per cent iron, and 58.2 per cent chromium. For reduction of 100 parts of this alloy 37 parts of carbon are necessary, the above reaction explaining the difference between the theoretical and the practical proportion of carbon necessary, if calculation is made on the assumption that the double carbide is not formed.

Carnot and Goutal isolated $Fe_3C.3Cr_3C_2$ from ferrochrome containing 59 per cent chromium and 9 per cent carbon.[a] They found $3Fe_3C.Cr_3C_2$ in chrome steel containing 2 per cent chromium and 2 to 0.5 per cent carbon. In the electric furnace Moissan obtained Cr_3C_2. By treating 50 per cent ferrochrome with hydrochloric acid Behren and Van Linge obtained Cr_3FeC_2 which corresponds closely to the double carbide isolated by Carnot and Goutal. Williams[b], using the electric furnace, obtained $3Fe_3C.2Cr_3C_2$. All of these researchers show the existence of double carbides of varying percentages but all consisting of Fe_3C and Cr_3C_2.

The characteristics of ferrochrome of different percentages of carbon are widely variable. All of the alloys described contain 60 per cent or more of chromium. Ferrochrome containing 0.5 per cent carbon is bright lead gray in color, with the structure parallel to the bed of cooling. It breaks with difficulty, has a high compressive strength, and is one and one-half times as magnetic as soft steel of about 0.2 per cent carbon.

Ferrochrome containing 1.8 per cent carbon is gray in color, and breaks into thin plates many of which show faces of one-third millimeter perpendicular to the bed of cooling. Naturally, it is a little magnetic, but on magnetizing it has more than twice the magnetism of soft steel.

The 2.5 per cent carbon ferrochrome has the gray color of polished aluminum. It is weak and is about as magnetic as soft steel. With 3.6 per cent carbon, the alloy has a bright-gray color. It has little brittleness and has magnetism equal to ferrochrome containing 1.8 per cent carbon. Ferrochrome containing 4.5 per cent carbon is dull gray, has little brittleness, and has magnetism equal to that of soft steel. Ferrochrome containing 5.5 per cent carbon has the gray color of bright iron. It breaks up a little, has a lower compressive strength, and a magnetism equal to that of 5.5 per cent carbon. With 7.5 and 9 per cent carbon the ferrochrome is gray, contains tin-gray oriented needles, breaks up, has no magnetism, and is very porous.

---

[a] Guillet, L., Étude Industriel des Alliages Métallique, p. 419.

[b] Robin, F., Traite des Métallographie, 1912, p. 301.

REDUCTION WITH SILICON AND OTHER REDUCING AGENTS.

Several United States patents have been issued for the reduction of metallic oxides by the use of silicon as a reducing agent. The reaction is as follows:

$$2FeO.2Cr_2O_3+4Si=2Fe.4Cr+4SiO_2$$

Thus for the reduction of 100 parts of ferrochrome containing 65 per cent chromium, 35 parts of silicon are necessary. In United States patents granted to F. M. Becket [a] based on this reaction it is claimed that a ferrochrome with a silicon content as low as 0.01 per cent or less can be made by this method, although this possibility is not shown in the researches of Neumann with the silicon percentage of the alloy high. Patents based on about the same reaction, with ferrosilicon as a reducing agent have been granted to E. F. Price.[b] These processes are expensive, the silicon content in the alloy tends to be high, and as a result they are not widely used in actual manufacture.

Keigelgen and Seward [c] reduce chromium oxide with calcium phosphide according to the reaction

$$8Cr_2O_3+3P_2Ca_3=3P_2O_5+9CaO+16Cr$$

With phosphide of iron they utilize the reaction

$$5Cr_2O_3+6PF_2=3P_2O_5+Cr_{10}Fe$$

The method is not commercially applied.

Becket [d] proposes the use of calcium carbide as a reducing agent. He claims that the calcium reduces the metals and that the carbon is oxidized or remains with the resulting alloy, according to the reaction

$$3FeO.3Cr_2O_3+4CaC_2=3Fe.6Cr+4CaO+8CO$$

The method has not been used much commercially because of the expense. For the reduction of 100 parts of ferrochrome containing 65 per cent chromium, 53 parts of calcium carbide are necessary.

---

[a] 854018, May 21, 1907; 866561, Sept. 17, 1907; 891898, June 30, 1908.

[b] 865609, Sept. 10, 1907; 852347, Apr. 30, 1907; 862996, Aug. 13, 1907.

[c] U. S. Patent 878966, Feb. 11, 1908.

[d] U. S. Patent 898173, Sept. 8, 1908.

Rossi,[a] using aluminum as a reducing agent in the electric furnace, has produced ferrochrome containing 68.24 per cent chromium, 1.85 per cent silicon, 1 per cent carbon, and 0.5 per cent aluminum from chromite containing 50.29 per cent Cr_2O_3, 16.01 per cent FeO, 10.72 per cent Al_2O_3, 4.62 per cent SiO_2, 16.61 per cent MgO, 0.01 per cent sulphur, and 1.15 per cent CaO.

REFINING OF FERROCHROME.

Decarburization of high-carbon ferrochrome is accomplished by melting the alloy with a slag of lime, chromite ore, and a little fluorspar, according to the following reaction:

$$2[2(Fe_3C.3Cr_3C_2)+3\ Fe]+7FeO.7Cr_2O_3=25Fe.Cr_2+28CO$$

For each 100 parts of completely decarburized alloy 39 parts of pure chromite ore are necessary, or for each 100 parts of ferrochrome containing 10.6 per cent carbon, 31.3 per cent iron, and 58.1 per cent chromium, 36 parts of pure chromite ore are necessary for complete decarburization. The resulting alloy would contain 66.6 per cent chromium and 33.4 per cent iron. In practice the lime is added simply to flux any silica in the ore, to assist in elimination of silicon in the ferrochrome, and to cause possible removal of carbon as calcium carbide, as the operation is performed in an arc furnace. The fluorspar makes the slag more fluid. Gin[b] claims that high temperature is not necessary for decarburizing, but his contention is not sustained in practice.

E. F. Price[c] proposes to decarburize ferrochrome by passing an oxidizing gas through the molten metal, but the process is not used in practice.

F. M. Becket[d] proposes to make a ferrochrome high in silicon, containing approximately 51.3 per cent chromium, 17.5 per cent iron, 30 per cent silicon, and 1.2 per cent carbon in a first stage. Then he proposes to remove the silicon by adding chromite in the proportion of 6 parts of chromite to 1 part of silicon in the alloy, this proportion of chromite being slightly in excess of that theoretically necessary to oxidize all the silicon to silica. He gets an alloy containing 70 per cent chromium, 28.9 per cent iron, 1 per cent carbon, and 0.10 per cent silicon. The necessity of such a refining process shows the weakness of methods using ferrosilicon or silicon as a reducing agent in that the percentage of silicon in the alloy can not be kept low in one operation without high losses of chromium in the slag.

---

[a] Rossi, A. J., Ferro-alloys: Min. Ind., vol. 12, 1903, p. 693.

[b] Gin, G., Decarburization of ferro-alloys: Trans. Electrochem. Soc., vol. 15, 1909, p. 225.

[c] U. S. patent 886858, May 5, 1908.

[d] U. S. patent 891898, June 30, 1908.

MANUFACTURE OF FERROCHROME.

Until the introduction of the electric furnace in 1899 ferrochrome was manufactured entirely in either the crucible or the blast furnace. The crucible was used only for the production of the higher grades, chromite being reduced with charcoal, and a flux of lime, borax, fluorspar, or water glass being used. In the blast furnace chromite is reduced with some difficulty, with the high fuel consumption of about 3 tons of coal or coke to 1 ton of ferrochrome produced. Theoretically, it should be possible to get a ferrochrome containing 65 per cent chromium from ore containing 60 per cent Cr_2O_3 and 20 per cent FeO, but generally a ferrochrome containing 30 to 40 per cent chromium and 6 to 12 per cent carbon is the product in the blast furnace. Little ferrochrome is now made by either the crucible or the blast furnace, because it can be made cheaper in the electric furnace in localities where electric power is cheap. A small amount of carbon-free ferrochrome is now made by the thermit process.

ORES AND RAW MATERIALS USED.

The greater part of the ores now used in the electric furnace manufacture of ferrochrome come from Turkey, New Caledonia, Cuba, and New South Wales. There are considerable deposits of chromite ore in Canada and California, but they are so far from the market that the production does not amount to much. The analyses of some of the ores are given below:

Analyses of chromite ores.

Component.	Source of ore.			
	Turkey.	New Caledonia.	California.	Cuba.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Cr_2O_3	51.7	55.7	52.68	50.0
FeO	14.2	13.2	15.30	18.57
Al_2O_3	14.1	16.2	11.40	12.44
MgO	14.3	9.8	16.23	13.38
SiO_2	3.5	.2	3.40	3.82
CaO	1.7	.25	....	2.16
H_2O	.3	1.05	.94	....
MnO	....	.2	.15	....
P_2O_5	....	.05	....	.45
S	....	....	....	.69

The foreign manufacturers use only chromite containing less than 0.1 per cent phosphorus and sulphur and about 50 per cent Cr_2O_3. They use no lime in the charge, as it has been found preferable by them to use pure materials and keep the amount of slag as low as possible. In most plants high-grade anthracite coal is used as the reducing agent. The only American manufacturers of ferrochrome, according to their patent specifications, use a lime slag. They sometimes use Cuban ore, which contains considerable phosphorus and sulphur. Coke or charcoal may be used instead of anthracite coal, but the latter is better, as it may be obtained in a more finely pulverized state, a form in which it makes a more intimate contact with the chromite, and consequently produces a better reduction. As the electric furnaces have not a high shaft it is not necessary to use a reducing material of high compressive strength.

TYPES OF FURNACES USED.

There are several types of electric furnace used in the manufacture of ferrochrome. All are constructed on the principle of the Sieman's crucible with a conducting hearth, or are similar to the Héroult steel furnace with vertical electrodes in series. In a conducting-hearth furnace the lining of the walls may be of chromite or, more commonly, magnesite or dolomite tar mixture, with a carbon block in the bottom; or, as in the Girod furnace, it may have a conducting hearth of iron rods buried in the refractory bottom; or, as in the Sieman's furnace, it may have a nonconducting hearth in which the lining of the hearth and walls is entirely of a noncarbon refractory, such as dolomite, magnesite, or chromite. The walls are thin, not over 9 inches thick, but the electrodes are far enough from them to allow the molten charge to freeze on the walls and thus form a highly refractory lining. Some furnaces were water cooled at first to assist this result, but few are now so constructed. Ferrochrome freezes to a certain extent on the bottom, so that molten metal does not have so much chance to come in contact with the carbon bottom.

PROCESS OF MANUFACTURE.

The process of manufacturing ferrochrome consists of mixing a charge of chromite and anthracite coal in proportions based upon the theoretical calculations given. The charge is shoveled into the open top of the furnace and around the electrodes. The furnace is charged at regular intervals so as to keep the top in an unfused condition. The ore is finely powdered, but the coal is about as it comes from the mine. There is some loss of ore that is carried off with the gases that escape at the top of the furnace. At intervals of two to four hours the ferrochrome is tapped off from the bottom into iron pots set on cars, from which it and any slag are dumped when solid. The slag and metal come out of the same tap hole. When cool the metal is broken with hammers to separate it from the slag, and is packed into kegs or boxes. In tapping an iron rod is used to open up the tap hole, which is plugged with fire clay.

Ferrochrome manufacture is carried on continuously, in some cases for two years, before the furnace is shut down for repairs. Ferrochrome containing as low as 5 per cent carbon can be made economically when produced directly from ore in one operation. It has been possible to produce an alloy containing as low as 2 per cent carbon in one operation, but great care in regulation of the charge and operation of the furnace is necessary. The slags from the average ferrochrome furnace making a 5 per cent carbon alloy run from 0.5 to 1 per cent Cr_2O_3.

The refining of the high-carbon grades of ferrochrome is done in an arc furnace where the alloy is subjected to a prolonged heating with a slag of chromite, lime, and fluorspar, proportioned to the amount of carbon and silicon to be removed and the silica that must be fluxed in the chromite used. The ferrochrome covered by this slag is heated at a high temperature for a length of time dependent on the carbon in the alloy. The resulting slag contains about 25 per cent Cr_2O_3 and is ground up and sent through the smelting furnace again, so that there is not much loss of chromium. By this method it is possible to reduce the carbon from 10 to 0.25 per cent, but the more usual low-carbon grade contains 0.5 per cent carbon. The percentage of carbon in the ferrochrome varies from 9.5 to 0.6 per cent carbon, but the iron increases with the decrease of carbon. This would seem to show that in refining, the iron oxide of the chromite is first reduced, the chromic oxide merely serving to keep a slag with excess chromium, thus preventing any final lowering of the percentage of chromium in the alloy. As the carbon is oxidized so is the silicon until the content is as low as 0.2 per cent, as compared with 2 to 5 per cent in the crude alloy. Aluminum is also considerably eliminated, and phosphorus and sulphur are reduced to a slight degree. Although the market is small for ferrochrome very low in carbon, the difference in price between the 9 per cent alloy and the 0.5 per cent product does not seem warranted. The refining expense is almost entirely the cost of power, and with the cheap power generally available at a ferro-alloy plant the expense is not as high as $300 per ton, the difference in price of the products mentioned.

Processes based on the use of silicon or some reducing agent other than carbon have not been commercially successful because the cost of such reducing materials as silicon, ferrosilicon, and aluminum is much higher than that of carbon. Also the products may be contaminated with the reducing material just as when carbon is used, so that a subsequent refining is necessary. Carbon-free ferrochrome for high-grade steels has, however, been successfully made by the thermit process, but the amount made in this way is comparatively small. Analyses of various grades of ferrochrome follow.

Analyses of typical ferrochromes.

Component.	Crucible.[a]	Blast furnace.[a]	Electric furnace.[b]				
			With 8 to 10 per cent carbon.	With 7 to 8 per cent carbon.	With 5 to 6 per cent carbon.	With 3 to 4 per cent carbon.	With 1 per cent carbon.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Chromium	19.8	41.39	64.5	63.5	64.0	64.0	63.5
Iron			22.0	21.5	28.5	31.0	35.0
Carbon	3.8	7.12	9.5	7.5	5.5	3.5	.6
Silicon		.21	2.25	5.8	.4	.3	.2
Aluminum			.80	.8	.5	.4	.10
Manganese	.33	1.84	.15	.15	.15	.15	.10
Calcium			.25	.25	.25	.30	.35
Sulphur			.04	.04	.04	.04	.03
Phosphorus		.052	.03	.03	.03	.02	.02

[a] Venator, W., Über Eisen Liegierungen und Metall für die Stahl Industrie: Stahl und Eisen, vol. 28, 1908, p. 41.

[b] Girod, P., Studies on the electrometallurgy of ferro-alloys and steel: Trans. Faraday Soc., vol. 11, 1911, p. 172.

POWER AND ELECTRODE CONSUMPTION.

The power consumption in a ferrochrome furnace of the Meraker Electric Smelting Co., at Kopperaaen, Norway, was recently given as 3 kilowatt-hours per pound, or 0.68 kilowatt-year per short ton in making a ferrochrome containing 5 per cent carbon. At Kanawha Falls, W. Va., ferrochrome was made in a crucible electric-arc furnace with a power expenditure of 3.6 kilowatt-hours per pound, or 0.72 kilowatt-year per ton.[a] This product contained 70.96 per cent chromium, 23.23 per cent iron, 5.21 per cent carbon, 0.5 per cent silicon, 0.008 per cent phosphorus, and 0.078 per cent sulphur. At both Kopperaaen and Kanawha Falls an ore containing about 50 per cent Cr_2O_3 was used. The Kopperaaen ferrochrome contains 65 to 70 per cent chromium. In the experiments of the writer, which have been described, a product containing 50 to 68 per cent chromium and 4.32 to 9.31 per cent carbon was obtained with an ore containing 46.35 per cent Cr_2O_3, 3.02 kilowatt-hours per pound or 0.69 kilowatt-years per ton. A 750-kilowatt furnace of the Alby-carbide type at Kopperaaen, operating continuously, uses on the average about 3 kilowatt-hours per pound of ferrochrome produced, or 0.68 kilowatt-year per short ton, when chromite ore containing 50 per cent Cr_2O_3 is charged; and the product contains 5 per cent or more of carbon and 65 per cent of chromium.

The electrode consumption in ferrochrome manufacture depends somewhat on the proportion of carbon in the ferro-alloy being produced, as, if the carbon of the charge be materially reduced, the electrode will be oxidized by the charge. With an open-top furnace the consumption varies from 50 to 100 pounds per short ton of ferrochrome produced. As most of the ferrochrome furnaces do not use continuously feeding electrodes this item will probably be kept at a much lower figure in the future. At present in many plants one-half to one-third of the electrode is not used, and, unless the works has its own electrode plant in which stumps can be made into new electrodes, this is lost so far as its electrode value is concerned. Aside from the electrode item, the repair and up-keep cost on a ferrochrome furnace is not high. The linings last one to three years without repair.

---

[a] Schoel, G. P., Manufacture of ferro-alloys in the electric furnace: Electrochem. Ind., vol. 2, 1904, p. 460.

COST OF MANUFACTURE OF FERROCHROME.

In the table following, estimates are made of the cost of manufacture of a ferrochrome containing 60 per cent chromium and 8 to 10 per cent carbon from chromite ore containing 50 per cent Cr_2O_3. The power figures and other data were gathered by the writer in Europe and the United States during the past year. The calculations are on the basis of two 750-kilowatt furnaces turning out a total of 6 tons of ferrochrome per 24 hours. The Norwegian plant is within 60 miles, the French plant within 200 miles, and the American plant assumed to be within 100 miles of seaboard. Labor conditions are considered to be as found in the various countries.

Cost of production of ferrochrome per ton (2,000 pounds).

Item.	Norway.		France.		United States.	
	Cost of unit.	Total cost.	Cost of unit.	Total cost.	Cost of unit.	Total cost.
3,000 pounds of chromite	$15.00	$20.50	$15.00	$22.50	$15.00	$22.50
500 pounds of coal	5.00	1.25	6.00	1.50	5.00	1.25
50 pounds of carbon electrodes	.04	2.00	.03	1.50	.04	2.00
0.68 kilowatt-year	8.30	5.65	18.66	12.70	26.66	17.65
Labor	[a] 1.00	8.33	[a] .80	6.66	[a] 1.50	16.60
Repairs	....	4.00	....	4.00	....	4.00
Amortization and depreciation at 5 per cent each	....	2.50	....	2.50	....	2.50
Interest on $50,000 at 6 per cent	....	1.50	....	1.50	....	1.50
General and packing	....	4.00	....	4.00	....	4.00
Total	....	51.73	....	56.86	....	72.00

[a] Minimum for eight hours.

The figures indicate that it costs $20.27, or 39.2 per cent, more to manufacture ferrochrome in the United States than in Norway. This increase is due to the higher price of power and increased labor cost here. The cheapest figure at which power can be obtained now in the eastern United States is $26.66 per kilowatt-year for electrometallurgical purposes. The duty on ferrochrome is to be 15 per cent ad valorem. The 8 to 10 per cent grade sells for $110 to $130 per short ton (see table following).

SELLING PRICES OF FERROCHROME.

Ferrochrome is sold on the basis of a chromium content of 60 per cent, the price varying with the percentage of carbon. As the percentage of chromium varies from a given grade of alloy, the price, based on the carbon percentage, is decreased or increased a certain amount for each per cent variation from 60 per cent chromium. This feature is shown in the following tabulation of prices current in Germany and the United States on January 1, 1913:

Prices of ferro-alloys and metals.[a]

GERMANY, F. O. B. DUISBURG.

Alloy.	1912			1913
	Oct. 1.	Nov. 1.	Dec. 1.	Jan. 1.
Ferrosilicon:				
Made in the blast furnace, basis 10 per cent silicon, 2,240 pounds, scale ±$0.96	$32.90	$34.90	$35.40	$36.80
Made in the electric furnace, basis 45 per cent silicon, 2,240 pounds, scale ±$1.51	73.00	70.00	68.00	70.00
Made in the electric furnace, basis 75 per cent silicon, 2,240 pounds, scale ± $1.65	129.00	126.00	126.00	126.00
Ferromanganese silicon, electric furnace, 2,240 pounds:				
50 to 55 per cent manganese, 23 to 28 per cent silicon	112.00	112.00	112.00	112.00
68 to 75 per cent manganese, 20 to 25 per cent silicon	112.00	106.50	106.50	106.50
50 to 55 per cent manganese, 30 to 35 per cent silicon	117.50	117.50	117.50	117.50
Ferromanganese, basis 80 per cent manganese, 2,240 pounds, scale ±$0.55	61.90	61.90	64.25	68.00
Ferrochrome:				
Carbon free, thermit process, basis 60 per cent chromium, 2,000 pounds, scale $8.95	500.00	500.00	550.00	550.00
Electric furnace—				
Refined No. I, 0.3 to 0.75 per cent carbon, basis 60 per cent chromium, scale $8.95, 2,000 pounds	436.00	436.00	436.00	436.00
Refined No. II, 1 to 2 per cent carbon, basis 60 per cent chromium, scale $7, 2,000 pounds	262.00	262.00	262.00	262.00
4 to 6 per cent carbon, basis 60 per cent chromium, scale $4.20, 2,000 pounds	105.00	112.25	118.50	133.00
Ferrotitanium (10 to 15 per cent titanium), per pound	.188	.188	.188	.188
Ferrotungsten, 85 per cent tungsten, 0.5 to 1 per cent carbon, per pound of tungsten contained	.75	.71	.75	.765
Ferromolybdenum, 70 to 80 per cent molybdenum, per pound of molybdenum contained	2.06	2.06	2.06	2.06
Nickel, 98 to 99 per cent nickel, per pound	.43	.43	.43	.43
Aluminum, 98 to 99 per cent aluminum, per pound	.20	.206	.213	.218
Tungsten metal, 96 to 98 per cent tungsten, per pound	.70	.72	.725	.72

UNITED STATES, F. O. B. PITTSBURGH, PA.

Ferromanganese, basis 80 per cent manganese, 2,240 pounds	....	....	....	$63.30
Ferrosilicon, blast furnace, f. o. b. Ashland, Ky.:				
10 per cent silicon	....	....	....	24.00
11 per cent silicon	....	....	....	25.00
12 per cent silicon	....	....	....	26.00
Ferrosilicon, electric furnace, 50 per cent silicon, 2,240 pounds	....	....	....	75.00
Ferrotitanium, 10 to 15 per cent titanium, f. o. b. Niagara Falls, N. Y., per pound in carloads	....	....	....	.08
Ferrovanadium, per pound of vanadium content	....	....	....	2.50

[a] Stahl und Eisen, vol. 33, 1913, p. 85 (revised).

USES OF FERROCHROME.

Ferrochrome is used extensively in the manufacture of steel for armor plates, armor-piercing projectiles, wire, bullet-proof steel, tool steel, high-speed steel, high-grade castings, stamp-mill shoes and dies, safe steel, tires, axles, springs, razors, file and cutlery steel, and for many other purposes. As shown int he table on page 138, electric furnace ferrochrome is made in five grades, of which those containing 4 per cent carbon are classed as refined, the carbon in the others being regulated in the charge to a certain extent.

Ferrochromes containing less than 2 per cent carbon are used in the manufactures of tool steels and high-speed steels. The alloy containing 3 to 4 per cent chromium is used principally in the manufacture of steel castings. For general open-hearth casting ferrochrome containing 4 to 6 per cent of carbon is used.

For the manufacture of armor plate and projectiles, the high-carbon ferrochromes containing 8 to 9 per cent carbon are generally used. This alloy is much cheaper and also its use is advisable for armor plate, because the carbon must be added at some time to harden the steel. A ferrochrome containing a high proportion of carbon used in the open-hearth furnace will give a yield much superior to that containing a low proportion of carbon, because if the metal is still slightly oxidized, the oxide will act on the carbon rather than on the chromium. For the purpose of protecting the chromium from oxidation, armor-plate manufacturers use a ferrochrome that contains a high percentage (4 to 5 per cent) of silicon. In this way the oxides act on the silicon before they act on the chromium.

The distinguishing feature of chrome steels is their great hardness.[a] Chrome steels usually contain 1 to 2 per cent chromium and 0.8 to 2 per cent carbon. Armor plate contains about 3.25 per cent nickel, 1.5 per cent chromium, and 0.25 per cent carbon. In armor plates the nickel and chromium are sometimes added in the form of a ferrochrome-nickel containing 52 per cent chromium, 18 per cent nickel, 28.96 per cent iron, 0.5 per cent carbon, 0.5 per cent silicon, 0.03 per cent sulphur, and 0.01 per cent phosphorus.

FERROMANGANESE.

HISTORY.

In steel manufacture more ferromanganese than any other ferroalloy is used. The industrial importance of ferromanganese began in 1866 with the introduction of the Bessemer process, which required a strong deoxidizing agent to produce a sound steel. In 1866, Prieger of Bonn, Germany, made in the crucible some ferromanganese containing 70 to 80 per cent manganese. At Terre-Noire, France, a little later it was made in the open-hearth furnace and crucible in a combination process. The first ferromanganese to be made in the blast furnace was produced in Sweden in 1873, and contained 33 per cent manganese. In 1875, at Terre-Noire, Pourcel made in the blast furnace some ferromanganese that contained 75 to 80 per cent manganese. Since that time up to a few years ago all ferromanganese was made in the blast furnace. At present a comparatively small quantity is made in the electric furnace, the greater part of that so made being used for the production of ferromanganese-silicon or silicomanganese. When the iron-manganese alloy contains less than 25 per cent manganese it is called spiegeleisen; when it contains more than 25 per cent it is called ferromanganese.

---

[a] Stoughton, Bradley, The metallurgy of iron and steel, 1908, p. 399.

EXPERIMENTS IN THE PRODUCTION OF FERROMANGANESE.

Stassano [a] in 1908 made some experiments in the production of ferromanganese in a 75-kilowatt electric furnace of the type of the Stassano steel furnace. The charge consisted of 1,000 parts of manganese ore, 300 parts of charcoal, 60 parts of lime, and 80 parts of 25 per cent sodium silicate used as a binder for briquets of the above composition, the form in which the charge was smelted. The ore used contained 45.65 per cent Mn_3O_4, 16.1 per cent Fe_2O_3, 3.05 per cent Al_2O_3, 30.16 per cent SiO_2, 0.15 per cent BaO, 1.2 per cent CaO, 0.43 per cent MgO, 0.817 per cent S, and 0.34 per cent P. The desired product was to be silicomanganese containing about 60 per cent manganese and 20 per cent silicon. The charge was submitted to the heat radiated from the arc as in all Stassano furnaces.

The product contained 17.76 per cent iron, 17.6 per cent silicon, 62 per cent manganese, 1.8 per cent carbon, 0.028 per cent phosphorus, and a trace of sulphur. No data showing the losses of manganese were given. The energy consumption was 3.86 kilowatt-hours per pound, or 7,560 kilowatt-hours, 0.86 kilowatt-year, per long ton.

THEORY OF PRODUCTION.

Ferromanganese is manufactured from manganese oxide ore with carbon as a reducing agent. Because of the high reduction point of manganese dioxide, 1,105° C., considerably more coke is necessary in the blast-furnace charge than in the iron blast furnace. Reduction takes place in the electric furnace according to the reaction—

$$MnO_2+2C=Mn+2CO.$$

For the reduction of 100 parts of manganese, 43.5 parts of carbon are necessary.

Carnot [b] and Goutal have shown the existence of the following double carbides of iron and manganese in ferromanganese of different percentages of carbon:

Double carbide.	Percentage of manganese.
$Fe_3C. 4 Mn_3C$	74 to 85
$Fe_3C. 2 Mn_3C$	60 to 74
$2Fe_3C. Mn_3C$	30 to 60
$4Fe_3C. Mn_3C$	below 18

---

[a] Stassano, E., Treatment of iron and steel in the electric furnace: Electrochem. and Met. Ind., vol. 6, 908, p. 315.

[b] Guillet, L., Étude industriel des alliages métalliques, p. 405.

The single carbide of manganese is Mn_3C, similar to Fe_3C, the carbide of iron.

Ferromanganese usually contains about 6 per cent carbon, when it is silvery white. When the silicon content in the alloy is low, the carbon is all in the combined state. With more than 5 per cent silicon the carbon falls to about 2 per cent, and as the silicon increases the carbon in the alloy decreases.

PROCESS OF MANUFACTURE.

Ferromanganese is still manufactured almost entirely in the blast furnace. When the manufacture of ferro-alloys in the electric furnace began, attempts were made to make ferromanganese. These failed, chiefly because of operation of the electric furnace at so high a temperature as to produce great volatilization of the manganese. As the electric furnace became better understood, heating by resistance only was found possible, thus insuring a low enough temperature.

Most of the blast-furnace ferromanganese used in this country, with the exception of that made by one large corporation, is made in England. Recently some German ferromanganese has been put on the market. Russian or Turkish manganese oxide ore is used. Ores high in silicon can not be used because of the high loss of manganese as silicate in the slag. The results of a typical blast-furnace run, including figures as to the ore used, and the slag and the alloy produced, are given in the table below. In this run the average amount of coke consumed was 2.37 long tons per long ton of ferromanganese produced. Of the total manganese charged 76.9 per cent was saved and 23.1 per cent lost. Of the total slag lost 6.7 per cent was in the slag and 18.4 per cent was volatilized or lost as dust.

Results of blast-furnace run to produce ferromanganese.[a]

Ore.		Slag.		Ferromanganese.	
Constituent.	Percentage.	Constituent.	Percentage.	Constituent.	Percentage.
Mn	51.6	SiO_2	30.32	Mn	80.20
Fe	1.45	FeO	1.41	Fe	11.80
P	.173	MnO	8.52	Si	1.16
SiO_2	7.80	Al_2O_3	10.88	P	.38
Al_2O_3	1.12	CaO	41.34	C	6.46
CaO	1.80	MgO	2.96		
MgO	2.18	P_2O_5	.01		
BaO	2.20	CaS	3.94		
		BaO	.48		

[a] Jakoki, J., Ferromangen in Hochofen; Stahl und Eisen, vol. 29, 1909, p. 1191.

The loss of manganese by volatilization, or as dust, varies between 15 and 30 per cent of the total quantity of manganese charged. The average total loss is about 30 per cent, of which 10 per cent goes to the slag and 20 per cent is volatilized or lost as dust. Any phosphorus in the ore goes to the metal, but there is no difficulty in slagging the sulphur. No more than 0.02 per cent of phosphorus should be present for each 10 per cent of manganese in the ore. The manganese as a rule is unevenly distributed through the alloy. Usually some limestone is necessary in the charge. The alloy produced in the run discussed above is high in phosphorus. An average English ferromanganese contains 83.4 per cent manganese, 9.04 per cent iron, 6.5 per cent carbon, 0.8 per cent silicon, 0.25 per cent phosphorus, and 0.01 per cent sulphur.

When ferromanganese is being made in the electric furnace, the electrodes and voltage are regulated so as to prevent arcking. With a mixture of 813 parts of ore containing 30 per cent manganese, 178 parts of anthracite coal (4 to 5 per cent ash), and 90 parts of fluorspar, about 450 pounds of product was obtained per ton of mixture treated. The product contained 85 per cent ferromanganese.[a] Of the total manganese charged 26.8 per cent was lost by volatilization, as dust, and in the slag. Ferromanganese made in the electric furnace has considerably lower carbon content than the blast-furnace ferromanganese, and is used in the molten state by the ferro-alloy manufacturer for making silicomanganese.

USES OF FERROMANGANESE.

The greater part of the ferromanganese manufactured is used in the deoxidation and recarburization of ordinary Bessemer and open-hearth steel. It is a strong deoxidizing agent and also assists in the elimination of sulphur from steel. In foundry work ferromanganese is used for softening, strengthening, and purifying hard or chilling iron. It is also employed for strengthening soft iron.

The next greatest use for ferromanganese is as a fixed addition in the production of manganese steel. When the manganese content of steel is more than 1 per cent, the metal becomes hard and somewhat brittle, and these qualities increase in intensity with every increase of manganese up to 4 to 5.5 per cent when the steel can be powdered under the hammer.[b] With 7 per cent manganese new properties appear, which are well marked in steel having a manganese content of 10 per cent, and reach a maximum with a manganese content of 12 to 15 per cent. Manganese steel usually contains 12 to 13 per cent of manganese and 1.5 to 2 per cent of carbon. With that proportion of manganese the strength and durability of the metal is at its maximum. When cooled slowly after casting manganese steel is almost as brittle as glass. It must be reheated and quenched at a high temperature in water. After such treatment it is as ductile as soft carbon steel or wrought iron, and its tensile strength is about three times as great. The hardness of the product after the latter treatment is almost the same as before, being so hard that machining is not practical. The forging and working of manganese steel is very difficult and is understood by only a few.

---

[a] Guillet, L., Étude industriel des alliages métalliques, p. 405.

[b] Stoughton, B., The metallurgy of iron and steel, 1911, p. 397.

Manganese steel is used for the jaws and wearing parts of rock-crushing machinery, for railroad frogs and crossings, for railroad rails on curves, for mine-car wheels, and for burglar-proof safes. Because of its great hardness without brittleness its life for the uses mentioned is many times that of all other steels.

FERROMANGANESE-SILICON.

Ferromanganese-silicon or silicomanganese is an alloy developed since use has been made of the electric furnace for ferro-alloy manufacture. Ferromanganese is made from manganese ore in an electric furnace operated as a resistance furnace, and ferrosilicon is made in a separate arc furnace. The two products are mixed while hot in a ladle, to form the alloy of the desired percentage of manganese and silicon. Ferromanganese containing about 85 per cent of manganese is made. The percentage of ferrosilicon depends on the amount of iron desired in the finished silicomanganese. The other method of manufacture is to mix coal, quartz, manganese, oxide ore, and iron turnings in the proper proportion to form the desired silicomanganese and smelt it all in one furnace which must be kept at a high temperature because of the high reduction point of silica. The great disadvantage of this method is the high loss of manganese by volatilization. This method, however, seems to be the favorite one, as it is quicker, only one furnace is involved in the process, and less labor is necessary. It should be noted from the table on page 140 that the price of silicomanganese does not increase with the manganese content but with an increase in the percentage of silicon. This is because much more energy is necessary for reduction of silica than of manganese oxide. A third method of manufacture is to reduce rhodonite ($MnSiO_3$) with carbon in the electric furnace. In this method coal or coke is mixed with rhodonite containing 38 per cent manganese, in the proportion of 600 parts of ore to 100 parts of coke. The electrode consumption is very high, being about 200 pounds per ton of product, and the power consumption is 5,400 kilowatt-hours or 0.62 kilowatt-year per ton. Keller adds ferrosilicon to a fused mixture of ferrosilicon, quartz, carbon, and manganese ore, claiming that the reduction temperature remains low and prevents volatilization of manganese.

Three grades of ferromanganese-silicon are made as follows: 50 to 55 per cent manganese, 23 to 28 per cent silicon; 68 to 75 per cent manganese, 20 to 25 per cent silicon; 50 to 55 per cent manganese, 30 to 35 per cent silicon. The carbon content in these alloys is low, owing to the action of silicon in breaking up the combined carbon in the ferromanganese, causing the carbon to separate as graphite, which rises to the surface of the bath. With less than 16 to 18 per cent silicon in the alloy, carbon remains in the combined state; with more than that percentage, any carbon present is in the form of graphite. Analyses of typical silicomanganese are given below:

Analyses of typical ferromanganese-silicon.

Constituent.	Analysis 1.	Analysis 2.	Analysis 3.
	Per cent.	*Per cent.*	*Per cent.*
Silicon	24.1	24.6	24.1
Manganese	74.2	70.3	55.0
Iron	.77	3.8	19.0
Aluminum		.4	.4
Calcium		.3	.3
Magnesium		.2	.2
Carbon	.30	.35	.35
Sulphur	.01	.02	.02
Phosphorus	.02	.04	.04

Alloys similar to those represented in analyses 1 and 2 are used for incorporating manganese and silicon in steel. The alloy is also used for deoxidizing, when a composition similar to that given in analysis 3 is generally employed. The product has the advantage over ferromanganese of being low in carbon, yet possessing as strong a deoxidizing power. Its use is especially advantageous in making high-grade manganesesilicon steel. Silicomanganese is usually added to the furnace just before the furnace is tapped, or in the casting ladle during tapping.

ELECTRIC SMELTING OF MOLYBDENITE AND THE PRODUCTION OF FERROMOLYBDENUM.

HISTORY.

Ferromolybdenum is generally manufactured in the electric furnace from the raw sulphide ore of molybdenum, molybdenite. It is also made by the reduction of the roasted sulphide with carbon in a crucible or an electric furnace. The alloy is not widely used because of its high cost, which is caused by the irregularity of the ore supply. With a better and steadier source of ore, ferromolybdenum would probably be used in place of ferrotungsten. Ferromolybdenum was made from roasted ore in the crucible before the introduction of the electric furnace, but has been produced commercially directly from the sulphide only since 1900, following the use of the electric furnace.

INVESTIGATORS.

Investigators of the electric smelting of molybdenite or of the production of ferromolybdenum are mentioned below, their methods being briefly outlined.

GUICHARD.

Guichard,[a] working with Moissan between 1890 and 1895, obtained a crude molybdenum from natural molybdenite by reduction with carbon in the electric furnace. This product was really a carbide, as it contained 91.8 per cent molybdenum, 2.1 per cent iron, and 6.64 per cent carbon. The operation was performed according to the following reaction:

$$2MoS_2+3C=Mo_2C+2CS_2$$

The difficulty in the process is to obtain pure metal from impure ores, because there is a tendency for any impurities to concentrate in the metal.

LEHNER.

Lehner[b] conducted a series of experiments on the production of a ferromolybdenum free from sulphur, using molybdenite in the electric furnace. After several unsuccessful experiments, in which the oxides of other metals were used to decompose molybdenite or in which the reducing agent was aluminum, he tried to accomplish the reduction in the electric furnace with a very basic slag, according to the following reaction:

$$MoS_2+2CaO+2C=Mo+2CaS+2CO$$

The results of some of his experiments are tabulated below:

Results of experiments of Lehner.

Experiment No.	1	2	3	4	5
Charge:					
MoS_2 .....pounds..	3.3	3.3	1.23	5.5	5.5
Fe_2O_3 .....do....	....	....	2.11	4.73	4.73
CaO .....do....	2.31	3.08	.86	[a]9.16	[a]9.16
Coke .....do....	.55	.85	.79	2.18	2.18
Product:					
Molybdenum .....per cent..	90.7	88.3	43.30	50.33	48.72
Iron .....do....	2.9	2.89	49.8	45.95	46.56
Carbon .....do....	4.1	5.60	6.27	1.70	1.06
Silicon .....do....	....	2.95	.31	1.51	2.61
Sulphur .....do....	.86	.04	.05	.10	.13

[a] $CaCO_3$.

These results show the possibilities of sulphur elimination by means of lime in the electric furnace, but do not show where the molybdenum losses occur—whether in the slag or by volatilization. An extraction of 85 per cent was made in experiment 2.

NEUMANN.

Neumann[c] attempted reduction of molybdenite according to the reaction:

$$MoS_2+Si=Mo+SiS_2.$$

---

[a] Guichard, M., Sur la molybdènite et la prèparátion au molybdene: Compt. Rend., vol. 122, 1896, p. 1270.

[b] Lehner, W., Herstellung von Molybdenum: Metallurgie, vol. 3, 1906, p. 549.

[c] Neumann, G., Herstellung von Ferroliegierung im electrischen Ofen: Stahl und Eisen, vol. 28, 1908, p. 356.

He obtained unsatisfactory results. The metal produced contained 2.87 per cent iron, 2.06 per cent silicon, and 13.89 per cent sulphur, the remainder being molybdenum. Upon this method, several patents issued to Becket are based.

EXPERIMENTS ON REDUCTION OF MOLYBDENITE.

An experiment was made by the writer,[a] who used the electric furnace described in the discussion of the ferrochrome experiments to test the possibility of sulphur elimination with a charge of molybdenum and excess lime, carbon being used as a reducing agent. The experiment was made directly after some experiments on the production of molybdenum steel directly from hematite and molybdenite, and can not be considered as quantitative, as the furnace lining was in poor condition. Some iron left in the furnace diluted the product. The electric furnace was regulated so that all heating was through resistance only. On tapping, 1.5 pounds of ferromolybdenum was obtained. The odor of sulphur was noticeable during the experiment. The product was brittle, but was not extremely high in sulphur in view of the amount of sulphur in the charge. There was 30 per cent sulphur in the ore, but only 0.19 per cent sulphur in the product. A commercial ferromolybdenum having 50 per cent of molybdenum contains about 0.03 per cent sulphur and 0.5 to 4 per cent carbon. The results of the experiment are shown in the table below. The coke, fluorspar, and lime had the composition given in the table on page 128.

Production of ferromolybdenum from molybdenite.

Ore.		Charge.		Metal.		Slag.	
Constituent.	Percentage.	Constituent.	Pounds.	Constituent.	Percentage.	Constituent.	Percentage.
Mo..........	47.5	Molybdenite	4.0	Mo..........	50.55	MoO_3........	3.18
Fe..........	1.23	Coke........	1.04	C..........	.73	CaO........	41.80
SiO_2........	13.90	Lime......	3.01	Si..........	.94	MgO........	12.75
P..........	.608	Fluorspar...	.25	P..........	.078	FeO........	7.56
S..........	30.64			S..........	.19		

From this experiment no conclusion can be drawn as to the loss of molybdenum, but in three runs made on the production of molybdenum steel from hematite and molybdenite with carbon as a reducing agent, the average total molybdenum loss was 46.1 per cent, of which 25.4 per cent was in volatilization and 20.7 per cent by slagging. Thus 56.2 per cent of the total molybdenum loss was by volatilization.

The conclusions made from the ferromolybdenum experiment were: First, that ferromolybdenum low in carbon can be made directly from molybdenite in the electric furnace, with excess lime as a desulphurizing agent and carbon as a reducing agent; second, that a product with a low percentage of carbon can be made; and, third, that sulphur can be readily slagged as calcium sulphide with a charge of excess lime.

---

[a] Keeney, R. M., The production of steel and ferro-alloys directly from ore in the electric furnace: Iron and Steel Inst., Carnegie Scholarship Memoirs, vol. 4, 1912, p. 108.

THEORY.

A ferromolybdenum containing 80 per cent molybdenum has a dull iron gray color, coarse structure, a high density, and is nonmagnetic. It does not break up easily. The 75 per cent alloy is about the same as the above, but has a needle structure, and when treated with another magnet is so magnetic that it has about three times the magnetism of soft steel.

A commonly used basis for calculating the charge for the reduction of ferromolybdenum from molybdenite is the reaction used by Becket in his patent.[a] Carbon is the reducing agent and lime is used as a desulphurizing agent. The reaction is as follows:

$$2MoS_2+2CaO+3C=2Mo+2CaS+2CO+CS_2.$$

Pure molybdenite contains 60 per cent molybdenum and 40 per cent sulphur. According to the above reaction, 100 parts of molybdenum are reduced from 170 parts of molybdenite by 18.8 parts of carbon. If the reaction is to be complete, for every 100 parts of molybdenum present as the molybdenite, 58 parts of lime are necessary for the slagging of the sulphur. If calcium carbonate instead of lime be used, the reaction is:

$$2MoS_2+2CaCO_3+5C=2Mo+2CaS+CS_2+6CO.$$

If calcium carbide be used as a reducing agent, the following reaction takes place:

$$5MoS_2+2CaC_2=5Mo+2CaS+4CS_2.$$

Becket, in his patent, states that an alloy containing less than 0.2 per cent carbon can be made by this method. Molybdenum does not combine as readily with carbon to form carbides as do some of the other metals, such as chromium and tungsten.

Becket was granted a patent[b] based upon the desulphurizing of molybdenite with silicon. The reaction involved is:

$$MoS_2+Si=Mo+SiS_2$$

Neumann's experiments indicate that the use of the latter reaction is not very satisfactory. By this method the production of 100 parts of molybdenum requires 29 parts of silicon, which would probably be used in the form of ferrosilicon, the iron in the ferrosilicon making the desired percentage in the ferromolybdenum.

---

[a] U. S. Patent 835052, Nov. 6, 1906.

[b] U. S. Patent 855157, May 28, 1907.

PROCESS OF MANUFACTURE.

Ferromolybdenum is manufactured commercially in an electric furnace of the electrode type operated as a resistance furnace, or in a crucible furnace of the resistance type. Comparatively little ferromolybdenum is made because of difficulty in getting ores, as satisfactory methods of concentrating molybdenite ores have not as yet been fully developed. There are deposits of molybdenite in the United States in Maine, Oregon, Colorado, Nevada, and Washington. There are also deposits in Canada, Germany, Japan, Mexico, New South Wales, New Zealand, Norway, Peru, and Queensland. Queensland and New South Wales are the largest producers. Buyers require an ore or a concentrate containing 90 to 95 per cent molybdenite, for which the price is about $450 per short ton. In commercial manufacture, raw or roasted molybdenite, iron turnings, lime, and coke or coal are mixed to give a ferromolybdenum of the desired proportions, and the mixture is treated in the electric furnace. The furnaces are operated intermittently; that is, one charge is completely discharged before another is added. Analyses of typical electric-furnace ferromolybdenum are given in the table following. Ferromolybdenum is first made as a high-carbon alloy containing 3 to 4 per cent carbon. This is then decarburized with a lime slag or a slag of lime and iron oxide. If the latter is used, the percentage of iron in the alloy is increased.

Analyses of typical ferromolybdenum.

Analysis No.	1	2	3	4
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Molybdenum	85.8	75.0	85.2	50.311
Iron	10.963	18.5	14.047	48.92
Carbon	3.07	4.0	.45	.35
Silicon	.11	.2	.252	.30
Aluminum	....	.1	....	....
Calcium	....	.15	....	....
Manganese	....	.15	....	....
Sulphur	.05	.03	.031	.030
Phosphorus	.007	.03	.02	.20

USES.

Ferromolybdenum in definite proportions is added to steel in the open-hearth crucible or in the electric furnace. It gives the steel properties similar to those of tungsten steel, but only one-third to one-quarter as much is necessary. Molybdenum is added to steel that is to be used for such forgings as crank and propeller shafts, for gun barrels, wire, boiler plates, armor-piercing shells, motor-car steel, magnet steel, and high-speed steel.

Molybdenum considerably increases the elongation and elastic limit of steel. By the addition of 0.25 per cent of molybdenum the elongation has been increased from 4 per cent up to 45 per cent. The addition of small quantities of molybdenum to nickel steels increases their resistance to blows without proportionally diminishing their elongation. A nickelchrome molybdenum steel has been used for armor plate.

Tempering has a much more energetic action in molybdenum steel than in carbon steels. If sufficient chrome is added to steels containing a high percentage of molybdenum, they lose a large part of their electricity, harden in the air, and have the same qualities as tungsten high-speed steels. The advantage in using molybdenum instead of tungsten in a high-speed steel is that it gives all the desirable qualities to high-speed steel, with the advantage that the carbon content is kept below 1 per cent, the hardness and brittleness of tungsten high-speed steels being thus avoided. Also, if ferromolybdenum could be produced as cheaply as ferrotungsten it would be more economical to use because of the decreased amount necessary to give the same qualities.

FERRONICKEL.

Nickel is usually incorporated in steel by the addition of metallic nickel rather than of ferronickel. Most of the ferronickel now used occasionally is made in a crucible furnace, fired by coal or gas, rather than in the electric furnace, as it is made by simply melting iron and nickel in the proper proportions. The metallic nickel used contains 99 per cent nickel. Ferronickel as supplied contains 25 per cent, 35 per cent, 50 per cent, 75 per cent, and 85 per cent nickel. The impurities in these alloys consist of 0.5 to 1 per cent carbon, 0.2 to 0.3 per cent silicon, 0.01 to 0.02 per cent sulphur, and 0.2 to 0.3 per cent phosphorus. It is claimed that these alloys give a more homogeneous mixture of nickel in the steel than is obtained by the use of the ordinary nickel metal. The alloy is malleable, homogeneous, and can be readily rolled, drawn, or worked. The ferronickel containing 25 per cent nickel is practically nonmagnetic.

EXPERIMENTS ON THE PRODUCTION OF NATURAL ALLOYS OF NICKEL DIRECTLY FROM ORE IN THE ELECTRIC FURNACE.

EXPERIMENTS AT SAULT STE. MARIE.

In 1907, during the course of the experiments on the production of pig iron in the electric furnace at Sault Ste. Marie, several runs were made on the reduction of roasted pyrrhotite with charcoal.[a]

---

[a] Haanel, E., Report on the experiments made at Sault Ste. Marie, Ontario, under Government auspices, in the smelting of Canadian iron ores by the electrothermic process: Mines Branch, Department of the Interior, Canada, 1907.

The furnace used in these experiments was similar in general design to that shown in figure 38. It took about 150 to 175 kilowatts. The results of the experiments are given in the table below:

Results of experiments on the production of ferronickel from roasted pyrrhotite.

Roasted pyrrhotite.		Charcoal.		Limestone.		Charge.	
Constituent.	Per cent.	Constituent.	Per cent.	Constituent.	Per cent.	Constituent.	Pounds.
SiO_2	10.96	Moisture	2.20	SiO_2	1.71	Ore	14,500
Fe_2O_3	65.43 (45.8 Fe)	Volatile matter	20.60	$Fe_2O_3+Al_2O_3$	.81	Charcoal	4,050
Al_2O_3	3.31	Fixed carbon	74.40	$CaCO_3$	92.85	Limestone	3,185
CaO	3.92	Ash	2.80	$MgCO_3$	4.40	Quartz	40
MgO	3.53			P	.004	Fluorspar	25
S	1.56			S	.052		
P	.016						
Cr	.41						
Ni	2.23						

Average analysis of ferronickel.		Average analysis of slag.	
Constituent.	Per cent.	Constituent.	Per cent.
Nickel	4.01	SiO_2	21.43
Copper	.71	Al_2O_3	11.60
Carbon	3.19	CaO	49.63
Manganese	.10	MgO	8.78
Silicon	4.90	MnO	.10
Phosphorus	.043	FeO	.28
Sulphur	.005	CaO	.015
		NiO	.018
		P_2O_5	4.46
		S	.02

Length of run, hours and minutes	56 20
Mean volts on furnace	36.12
Mean amperes on furnace	5,000
Power factor	.919
Kilowatts	165.9
Ferronickel tapped, pounds	7,336
Kilowatt-hours per pound	1.27
Kilowatt-years per ton	.29

The furnace was later used in the production of ferronickel. The results of the work done later is given in the report by the metallurgist of the company that purchased the furnace. The ore and raw materials were of about the composition given for those substances in the table above. Four hundred pounds of briquetted roasted ore, 140 to 150 pounds of limestone, and 120 pounds of charcoal were the proportions used. During four months of operation, 154 short tons of ferronickel of approximately the composition given was produced, with a power consumption of 0.34 kilowatt-year per ton. The electrode consumption was 40 pounds of amorphous carbon per ton of ferronickel. To produce a product containing 4 per cent nickel, 2.75 per cent silicon, 0.8 per cent copper, 0.01 per cent sulphur, and 0.03 per cent phosphorus, on the average 2 tons of roasted pyrrhotite (2 per cent sulphur), 1,500 pounds of limestone, and 1,200 pounds of arcoal were used.

The results of the operation of the furnace show the possibility of producing a low-grade ferronickel directly from roasted ore in the electric furnace. Owing to the low percentage of nickel in the ore a high percentage of nickel could not be concentrated in the metal. There was difficulty in selling the product, so that after a short period of operation the work was discontinued. The product was not pure enough or high enough grade for steel manufacture.

EXPERIMENTS AT PLANT IN NORTH CAROLINA.

A plant was erected at Webster, Jackson County, N. C., where experiments were conducted on the reduction of garnerite in the electric furnace with coke as a reducing agent.[a] The furnace used was similar to the one shown in figure 41. The ores used were garnerite, containing 7.3 per cent Ni., 37.5 per cent SiO_2, 29 per cent Al, 1.8 per cent Fe, 10 per cent Mg, 0.1 per cent CO, and 11.9 per cent H_2O, and dunite, containing 1.7 per cent Ni, 41.8 per cent SiO_2, 6.7 per cent Al, 8.3 per cent Fe, 28.2 per cent Mg, 0.02 per cent CO, and 10.9 per cent H_2O. About 10 per cent of coke was used. The product made was a nickel silicide containing 10 to 30 per cent nickel, 20 to 30 per cent silicon, 40 to 50 per cent iron, 5 to 10 per cent Al, 3 to 5 per cent Cr, and 3 to 4 per cent of carbon, magnesium sulphur, and phosphorus. The average power on the furnace was 200 kilowatts. About 7,800 pounds of ore was smelted per 24 hours.[b] In a typical run 6.3 kilowatt-hours was used per pound of nickel silicide produced. The silicide contained 11.9 per cent nickel. The plant is no longer in operation. Power was very expensive at the point of erection of the experimental plant. It was stated to cost $200 per kilowatt-year.

EXPERIMENTS OF STEPHAN.

In 1903, at the works of the Société Anonyme Électrométallurgique Procédés Paul Girod, Stephan worked on the production of a nickel silicide from a silicon ore of nickel.[c] The product contained 30 per cent nickel and 47.20 per cent silicon. In 1911, experiments were performed at the same works in an attempt to make a ferronickel containing 3 to 5 per cent silicon.

The furnace used was of the type shown in figure 43. It was of 220 kilowatts capacity and treated 8 tons of ore, with the production of 770 pounds of metal, in 24 hours. The power consumption was 1,760 kilowatt-hours per ton of ore treated, or 6.86 kilowatt-hours per pound of alloy obtained. In practice it is believed the power consumption could be reduced to 1,200 kilowatt-hours per ton of ore, or, on the basis of the same percentage extraction, to 4.69 kilowatt-hours per pound of alloy. The results of the experiment are shown below:

---

[a] Anon., Electric smelting of nickel ore: Met. and Chem. Eng., vol. 8, 1910, p. 277.

[b] Morrison, W. L., Electric-furnace treatment of nickel ore and the development of a commercial process: Trans. Am. Electrochem. Soc., vol. 20, 1911, p. 315; Met. and Chem. Eng., vol. 4, 1911, p. 546.

[c] Stephan, M., Einiges über die Erzengang von Metallen im elektrischen Ofen: Metal und Erz, vol. 1, 1912, p. 11.

Results of Stephan's experiments on the production of ferronickel.

Ore.		Ferronickel.		Slag.	
Constituent.	Per cent.	Constituent.	Per cent.	Constituent.	Per cent.
NiO	8.33	Nickel	41.50	NiO_2	0.31
SiO_2	28.58	Iron	51.6	SiO_2	53.98
Fe_2O_3	14.61	Silicon	4.33	FeO	1.56
MgO	20.65	Silicide	Trace.		
Al_2O_3	2.33	Aluminum	.81		
H_2O	12.32	Carbon	1.34		
Moisture	12.54	Sulphur	.04		

FERROPHOSPHORUS.

Ferrophosphorus is made in the electric furnace from apatite or other phosphorus-bearing mineral. It is used in the open hearth for enriching the slag so as to get phosphorus into the steel, as steel for sheet purposes, particularly tin plates, can be rolled more satisfactorily if it contains phosphorus. Two grades of ferrophosphorus are used. One contains 16 to 20 per cent phosphorus and has the following analysis: 17.5 per cent phosphorus, 76.2 per cent iron, 0.42 per cent silicon, 0.27 per cent carbon, and 5.75 per cent manganese. The other grade contains 20 to 25 per cent phosphorus and has 24.0 per cent phosphorus, 73.3 per cent iron, 2.47 per cent silicon, 0.03 per cent carbon, 0.08 per cent sulphur, and 0.10 per cent manganese. Alloys containing phosphorus and manganese are also made. Some ferrophosphorus is made in Canada in the electric furnace, but most of it comes from Europe, except what is produced by a blast furnace in Tennessee.

FERROSILICON.

HISTORY.

Ferrosilicon is the most extensively used of all the ferro-alloys produced in the electric furnace. If all ferro-alloys be considered, it is second only to ferromanganese in amount consumed. Ferrosilicon was first prepared in 1810 by Berzelius [a], who, with a mixture of iron shavings, silica, and carbon, obtained an alloy containing 9 per cent silicon. In 1811, Strohmayer [a] repeated the experiments of Berzelius and prepared a series of alloys containing 2.2 to 9.3 per cent silicon. Valten [b] made ferrosilicon at Terre-Noire in 1872 by the reduction of iron oxide and silica in a crucible with carbon. There was 10 to 12 per cent silicon in the product. Using iron turnings, silica, and carbon, he obtained an alloy containing 22 per cent silicon. In 1875 Pourcel made 15 per cent ferrosilicon in the blast furnace at Terre-Noire. Silicospiegel was made at the same time in the blast furnace of Pourcel. From that time on, the manufacture of ferrosilicon in the blast furnace became firmly established. Moissan[a] in his electric furnace work made some ferrosilicon and silicides. The first company to take up the manufacture of ferrosilicon in the electric furnace was a company in West Virginia operating under the Chalmot patents[b] in 1898. Thus the manufacture of this important alloy in the electric furnace was begun in the United States, but to-day comparatively little is produced in this country. Blast-furnace ferrosilicon had been manufactured for many years previous to this in the United States. In 1899 the carbide industry in Europe began to collapse, and the manufacture of ferro-alloys was commenced. The first product made was ferrosilicon, the production of which was commenced in 1899 at Bozel, France, under the patents of Rothenau.[c] This was followed by a plant at Meran, Switzerland, in 1900, a plant at Giffre, Switzerland, in 1901, and plants at Matrei, Austria, and at Notre Dome de Briarçon, Ugine, Livet, and Albertville, France, in 1902. There are to-day many other plants in France, Germany, Switzerland, Austria, Norway, and Sweden. In the United States there is but one producer, a company that operates an old aluminum plant at Kanawha Falls, W. Va., and also one at Niagara Falls, N. Y. It is said that not all of the ferrosilicon sold by this company is manufactured in this country, some being imported. At Welland, Ontario, Canada, there is a ferrosilicon works producing about 4,000 tons yearly. The product contains 50 per cent of silicon. Some of it is exported to the United States.

---

[a] Conrad, W., and Pick, W., Die Herstellung von Hochprozentigem Ferrosilizium im elektrischen Ofen, 09. Revue de Métallurgie, vol. 9, 1912, p. 362.

[b] Guillet, L., Étude industriel des alliages métallique.

THEORY.

SILICIDES OF IRON.

A silicide of iron in the proportion 87.28 per cent iron and 11.01 per cent silicon was found in a meteor by Shepard in 1859. Carnot and Goutal[d] isolated the silicide $(FeMn)_3Si$ by treatment of a silicon spiegel with sulphuric acid. This corresponds in silicospiegel to the silicide Fe_3Si, 85.714 per cent iron and 14.286 per cent silicon, that possibly exists in ferrosilicon. Naske[e] tried to obtain pure Fe_3Si by treating a ferrosilicon containing 13.19 per cent silicon with ammoniacal copper chloride, but was unsuccessful. By treating a 10 per cent ferrosilicon with sulphur, he obtained a magnetic product which resembled a mixture of FeS and Fe_3Si. Although the silicide Fe_3Si has not been actually isolated, its existence seems probable by analogy with cemantite Fe_3C and $(FeMn)_3$ C. Fe_3Si is decomposed after a long time by dilute sulphuric acid, and is dissolved by hydrochloric acid from all silicides containing less than 20 per cent silicon. It is not attacked by dilute nitric acid.

---

[a] Moissan, H., Action du silicum sur le fer, le chrome et l'argent: Compt. Rend., vol. 121, 1895 p. 621.

[b] U. S. patents Nos. 602975 and 602976, Apr. 26, 1898.

[c] Carnot, and Goutal, Recherches sur l'etat où se trouvent le silicium et le chrome dans les produits siderurgiques: Compt. Rend., vol. 126, 1898, p. 1240.

[d] Carnot, and Goutal, Loc. cit.

[e] Conrad, W., and Pick, W., Die Herstellung von Hochprozentigem Ferrosilizium in elektrischen Ofen, 1909. Rev. de Métallurgie, vol. 9, 1912, p. 362.

The silicide Fe_2Si, 80 per cent iron and 20 per cent silicon, has been isolated from commercial products by Carnot and Goutal,[a] by Osmond,[b] and by Lebeau.[c] Carnot treated ferrosilicon with dilute nitric acid and ammoniacal copper chloride and Goutal treated it with warm dilute nitric acid. Hahn obtained Fe_2Si by synthesis, fusing iron chloride, sodium chloride, amorphous silicon, sodium, and fluorspar. In the electric furnace Moissan[d] heated iron oxide and crystallized silicon to obtain Fe_2Si. Lebeau obtained it by heating a mixture of iron and cuprosilicon.

Fe_3Si forms small prismatic crystals of metallic appearance. It is magnetic and has a specific weight of 7. It is not attacked by either dilute or concentrated nitric acid. It is dissolved easily by hydrochloric acid, with more difficulty by aqua regia, and completely by hydrofluoric acid. In alkaline solution it is dissolved completely only in hot concentrated solution.

The silicide Fe_3Si_2, which is found frequently in industrial products bearing 25 to 28 per cent silicon, contains 75 per cent iron and 25 per cent silicon. It forms octahedral crystals and has a specific gravity of 6.7. It is as magnetic as Fe_3Si and Fe_2Si. It is stable in the presence of all acids. Chlorine or bromine attacks it when at a red heat. According to Gin, it is decomposed at a high temperature into Fe_2Si and Si.

The best known silicide of iron is FeSi, 66.67 per cent iron and 33.33 per cent silicon. This alloy was prepared by synthesis by Fremy, through the action of silicon chloride upon iron, and by Lebeau through the action of cuprosilicon on iron. Lebeau also isolated FeSi from ferrosilicon containing 35 per cent silicon. FeSi crystallizes in tetrahedral needles. Its specific weight is 6.17, and its hardness about 7. When cold it is attacked by fluorine; at a dull red heat it is attacked by bromine and chlorine, by an alkaline fusion, by hydrofluoric acid, or by a mixture of hydrofluoric and nitric acids.

The silicide $FeSi_2$, 50 per cent each of iron and silicon, has been little studied. It has been prepared by Hahn and Lebeau by synthetic methods. Chalmot treated 39 to 50 per cent ferrosilicon with cold dilute hydrofluoric acid to obtain it. • Its specific weight is 5.4 and its hardness 4 to 5. Hydrofluoric attacks it only in concentrated solution, and the other acids have no effect upon it.

---

[a] Carnot, and Goutal, Researches sur l'etat où se trouvent le silicium et le chrome dans les produits siderurgiques: Comp. Rend., vol. 126, 1898, p. 1240.

[b] Osmond, F., Recherches calorimetriques sur l'état du silicium et de l'aluminium dans les fers fondus: Compt. Rend., vol. 113, 1891, p. 474.

[c] Conrad, W., and Pick, W., Die Herstellung von Hochprozentigem Ferrosilizium im elektrischen Ofen, 1909. Rev. de Métallurgie, vol. 9, 1912, p. 362.

[d] Moissan, H., Action du silicium sur le fer, le chrome et l'argent: Compt. Rend., vol. 121, 1895, p. 621.

The silicide $FeSi_3$, 40 per cent iron and 60 per cent silicon, is also little known. Naske obtained it from a ferrosilicon by treatment with hydrofluoric acid. It was in the form of a crystalline powder, which was insoluble in all solvents and attacked with difficulty by carbonate fusion. Pick claims that this silicide exists only in ferrosilicon containing a high percentage of silicon.

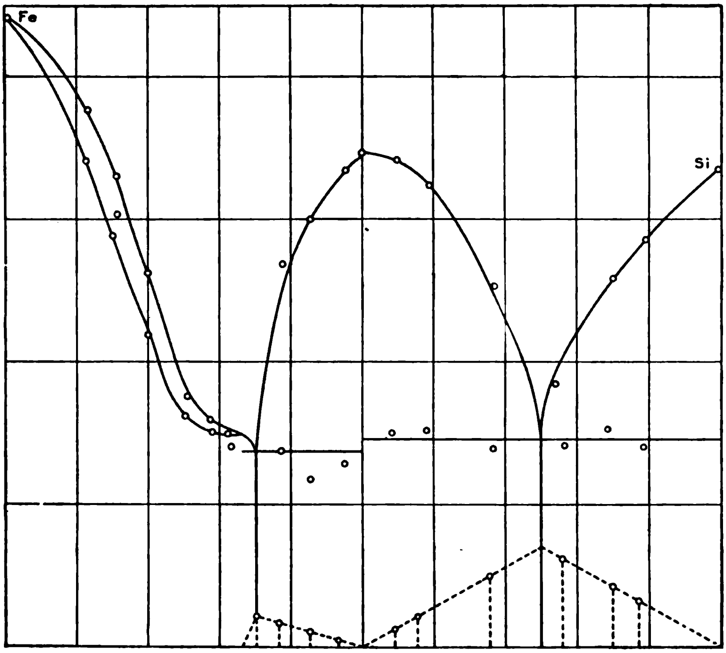


FIGURE 53.—Cooling curves of the iron-silicon system.

Tamman [a] and Gürtler have obtained the cooling curves of the iron-silicon system (fig. 53). They show the existence of only two silicides, Fe_2Si and $FeSi$, but from work of others it seems that there surely exist three, Fe_2Si, $FeSi$, and $FeSi_2$, and perhaps two others, Fe_3Si and $FeSi_3$.

The resistance of silicides of iron to acids increases and the specific weight and magnetic power decrease when the silicon content increases. They all have a good electrical conductivity and are disintegrated by carbonate fusion more or less easily according to their silicon content.

---

[a] Conrad, W., and Pick, W., Die Herstellung von Hochprozentigem Ferrosilizium im elektrischen Ofen, 1909. Rev. de Métallurgie, vol. 9, 1912, p. 362.

PROPERTIES OF FERROSILICON.[a]

Ferrosilicon always has a crystalline appearance. If its silicon content is less than 20 per cent it is dull, shows a fine crystallization, and resembles white iron. With a silicon content of 20 to 30 per cent the crystals become more brilliant and show a slaty crystallization. With a silicon content of 50 per cent or more, the crystallization disappears and is replaced by a fine texture resembling more and more silicon. It is not difficult to judge the percentage of silicon by the eye, according to the texture and the color of the fractured surface. As the percentage of silicon increases to more than 50 per cent, the ferrosilicon takes on a bluish color.

The various grades of commercial ferrosilicon are substantially binary alloys. Two compounds, Fe_2Si and FeSi, exist. The microstructure indicates two eutectics, one containing 21.6 per cent silicon (Fe_2Si and FeSi) and the other containing 60 per cent silicon (FeSi and Si). With a silicon content of less than 20 per cent the alloys consist of solid solutions of Fe and Fe_2Si, which are hard, firm masses giving off little or no gas. Alloys with a silicon content of 20 to 21.6 per cent silicon consist of primary crystals of Fe_2Si in a ground of a eutectic composed of Fe_2Si and FeSi. These alloys are more brittle than the lower grades. With a silicon content of 21.6 to 33.3 per cent, the structure shows FeSi surrounded by the eutectic Fe_2Si and FeSi. With a silicon content of 33.3 to 60 per cent there are crystals of FeSi in the eutectic FeSi and Si. With more than 60 per cent of silicon there exist silicon crystals in a field of the eutectic FeSi and Si.

With a silicon content of 30 per cent or less, ferrosilicon is hard and has no tendency to disintegrate spontaneously. Samples containing 30 to 65 per cent silicon show a decided tendency to spontaneous disintegration. They crumble on keeping, and some of them actually fall to powder after a few weeks. This spontaneous disintegration is usually accompanied by the evolution of bad-smelling and poisonous gases. Although samples with a silicon content of 70 to 96 per cent are somewhat brittle, they are not so easily broken and reduced to powder as those containing between 30 and 65 per cent silicon, and they do not show a tendency to disintegrate spontaneously.

The specific gravity decreases as the percentage of silicon increases, because the specific gravity of pure iron is 7.8, whereas that of pure silicon is 2.49. In figure 54 a curve representing the results of determinations of the specific gravity of various samples of commercial ferrosilicon, made by Dr. Hahe, of the British Local Government Board, is shown in comparison with the theoretical curve representing the calculated specific gravities for all percentages on the assumption that mixtures of iron and silicon are formed without change of volume. A comparison of the two curves shows that the assumption is not correct, that the specific gravities are partly above and partly below the theoretical curve, and that contraction of volume occurs in the alloys containing 60 per cent or less of silicon, and expansion of volume in alloys containing more than 60 but less than 96 per cent silicon, presumably owing to the presence of definite silicides of iron in the alloys.

---

[a] Copeman, S. M., Bennett, S. R., and Hahe, H. W., Yellow book of British Local Government Board the Manufacture, Uses, and Transport of Ferrosilicon, 1910: Met. and Chem. Eng., vol. 8, 1910, p. 133.

According to the diagram of Tamman and Gürtler (fig. 53), the fusing point of 25 and 50 per cent ferrosilicon is 1,360° C. The melting point of silica is 1,425° C., and of iron 1,540° C.

The chemical purity of the product decreases slightly with decrease in the silicon content. Compared with the impurities of the blast-furnace alloys, the impurities in electric-furnace ferrosilicon are low. The calcium content in the 25 per cent grade is about 0.5 per cent, and increases to 0.7 to 1 per cent for 90 per cent ferrosilicon. The magnesium content varies from 0.10 per cent in the 25 per cent grade to 0.3 per cent in the 90 per cent grade. The average aluminum content in all grades is between 0.1 and 0.15 per cent. In the blast-furnace ferrosilicon the percentage of carbon is 1 to 1.5 per cent. This diminishes with increase in the silicon content, so that in the 25 per cent grade there is about 0.35 per cent carbon, and in the 90 per cent grade the carbon content is as low as 0.2 per cent. The phosphorus content is generally less than 0.10 per cent, the sulphur content less than 0.05 per cent, and the manganese content less than 0.4 per cent.

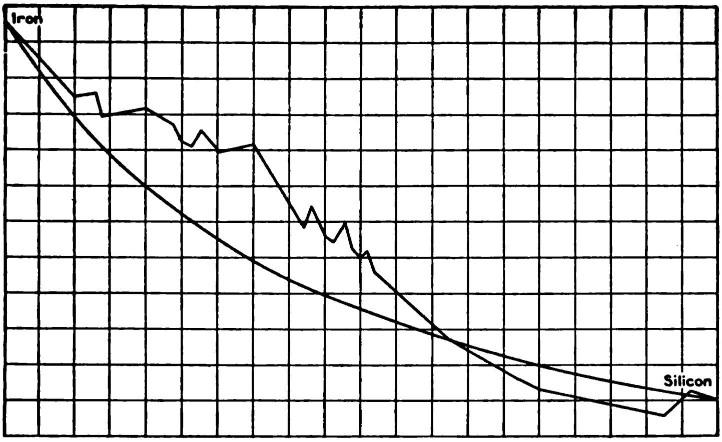


FIGURE 54.—Specific gravity curves of ferrosilicon samples containing varying percentages of ferrosilicon. Irregular line represents results of actual determinations. Uniform curve represents calculations based on assumption that mixtures of iron and silicon are formed without change of volume.

DISINTEGRATION AND EVOLUTION OF GAS FROM FERROSILICON.

As has been stated, a ferrosilicon containing between 30 and 65 per cent silicon has a tendency to disintegrate. It is not known whether this property is inherent in these grades, or whether it is due to chemical or physical conditions. The main impurity that might cause disintegration is calcium. If the calcium were present in the state of a silicide, the alloy would be stable, but if the calcium were present as calcium carbide, the alloy would be very unstable. The presence in ferrosilicon of calcium as calcium carbide might be due to the manufacture of ferrosilicon in an old carbide furnace. In a new furnace there should be no contamination by carbide.

It has been noticed that disintegration occurs in spots. In a mass of ferrosilicon of uniform composition, part will stay solid and part break up. Coating the product with paraffin has been tried, but is no longer believed to be efficacious, as it affects only the surface. Some persons believe that disintegration is affected by the temperature of pouring and the density of the current of electricity in the electrodes. When the temperature is high and the amount of current great, the product seems to be more subject to disintegration. It is possible that there is a phenomenon analogous to the allotropic changes of certain elements, such as sulphur. The solid parts have a homogeneous structure and grain, whereas the substance affected by disintegration consists of crystals surrounded by a powder.

There is evolution of explosive and poisonous gases from these grades of ferrosilicon when the alloy is in moist air and when there is friction between the particles of the alloy as in transportation. Dupre and Lloyd[a] attribute the explosions to acetylene gas made to ignite by the presence of small quantities of phosphide of hydrogen (PH_3), and when this is not present by sparks from attrition of particles of ferrosilicon. Wilson[a] found silicide of hydrogen. Ashenary[a] believed the gas to be hydrogen. Most investigators believe the poisonous gas to be PH_3, as phosphide of calcium and phosphide of iron are not decomposed by water.

In his report to the British local government board, Hahe states that he found phosphoretted hydrogen (PH_3) and arseniuretted hydrogen (AsH_3). He did not find in the samples tested any siliciuretted hydrogen (SiH_4) nor acetylene (C_2H_2), although others report those gases present as in ferrosilicon. It is probable that the poisonous emanations are phosphoretted hydrogen and arseniuretted hydrogen evolved by the action of water.

The formation of these gases is due to the presence of small quantities of calcium phosphate [$Ca_3(PO_4)_2$] and arsenic in the raw materials. Calcium phosphate occurs in coal and quartz. In itself it is harmless. It is insoluble in water and is common in nature. In the electric furnace, in the presence of carbon, it is reduced to calcium phosphide (Ca_3P_2). The calcium phosphide remains in the ferrosilicon and in contact with water in moist air is decomposed with evolution of phosphoretted hydrogen (PH_3), which is very poisonous. Arsenic occurs in nature closely associated with phosphorus, and finds its way into the ferrosilicon as calcium arsenide, which is decomposed by water or moist air, with the formation of arseniuretted hydrogen (AsH_3), also a poisonous gas.

---

[a] Conrad, W., and Pick, W., Die Herstellung von Hochprozentigem Ferrosilizium im elektrischen Ofen, 1909. Rev. de Métallurgie, vol. 9, 1912, p. 362.

These gases are evolved only by the grades of ferrosilicon that disintegrate easily—containing 30 to 65 per cent silicon. The British Government board classed as dangerous all grades that contained between 30 and 70 per cent silicon.

REDUCTION WITH CARBON.

Ferrosilicon is made commercially in two ways only—by the reduction of silica and iron ore with carbon or by the reduction of silica with carbon, the iron being added as iron turnings, which are simply melted. The utilization of siliceous and ferruginous slags has been proposed, but has not been adopted commercially, and experiments of the writer indicate that it does not seem practicable.

Silica is reduced by solid carbon at a temperature of 1,485° C. The reduction point of silicon is lowered if there is iron present in the charge to combine with the silica.[a] With a charge composed of 20 parts of silica, 30 parts of iron, and 8 parts of carbon the temperature of reduction was lowered to 1,200° C. in experiments performed by Greenwood. In commercial practice the presence of iron to lower the reduction temperature is important, as is shown by the fact that furnaces working upon a low-silicon product, with a large charge of iron operate better than when treating a high-silica product with a low iron charge.

Reduction takes place according to the formula:

$$SiO_2+2C=Si+2CO.$$

Thus, the reduction of 100 parts of silicon from 214 parts of silica requires 86 parts of carbon. The reduction of iron oxide is generally by the solid carbon only, according to reaction:

$$Fe_2O_3+3C=2Fe+3CO.$$

By this formula for the reduction of 100 parts of iron from 143 parts of hematite 32 parts of carbon is necessary. In the usual ferrosilicon furnace there is no shaft, so that reduction results mainly in the formation of gas, the greater part of which is carbon monoxide, as shown in the above formula.

---

[a] Greenwood, H. C., Sluele, R. E., Prinz, J. N., Reduction of refractory oxides, production of ferro-alloys and formation of carbides. Trans. Chem. Soc. (England), vol. 93, 1908, p. 1484. Electrochem. and Met. Ind., vol. 7, 1909, p. 119.

In the calculation of theoretical power consumption the following constants are used:[a]

Reduction or oxidation.	Calories absorbed.
1 kg. Fe from Fe_2O_3	1,746
1 kg. Si from SiO_2	6,428
1 kg. C to CO	2,430

The specific heat of iron for temperatures ranging from 0° to 1,400° C. is taken as the average 0.20; of silicon for temperatures ranging from 0° to 1,400° C., 0.25; and of carbon for a similar range, 0.50.

Theoretically the energy necessary for the reduction of 1 kg. (2.2 pounds) of silicon from silica is the result of dividing 6,428 by 857, or 7.5 kilowatt-hours per kilogram (3.4 kilowatt-hours per pound). The amount of energy necessary to reduce a long ton of pure silicon would then be 7,600 kilowatt-hours, or 0.87 kilowatt-year, per ton.

PRODUCTION FROM IRON ORE OF FERROSILICON CONTAINING 30 PER CENT SILICON.

In the calculations following, relative to producing ferrosilicon containing 30 per cent silicon from iron ore, the assumptions made are: First, that the iron of the alloy is to be reduced from a pure hematite ore 70 per cent iron; second, that the ferrosilicon is to contain 30 per cent iron and 70 per cent silicon; third, that the silicon is to be from a pure quartz containing 46.7 per cent silicon; and, fourth, that the reduction is to take place according to the given reactions. The calculations follow:

Reduction.		Calories required.
700 kg. Fe from Fe_2O_3	700×1,746	1,222,200
300 kg. Si from SiO_2	300×6,428	1,928,400
Heating.		
700 kg. Fe to 1,400° C	700×1,400×0.2	196,000
300 kg. Si to 1,400° C	300×1,400×0.25	105,000
482 kg. C to 1,400° C	482×1,400×0.5	337,400
Total		3,789,000
Amount of heat supplied:		
By combustion of 482 kg. C	482×2,430	1,171,260
By the electric current		2,617,740
Total		3,789,000

Therefore, the theoretical amount of electrical energy necessary for the production of 30 per cent ferrosilicon from iron ore and quartz is the result of dividing 2,617,740 by 857, or 3,054 kilowatt-hours per metric ton, or, in terms of the long ton, 3,109 kilowatt-hours, or 0.35 kilowatt-year per long ton.

---

[a] Richards, J. W., Metallurgical calculations, 1906, vol. 1.

PRODUCTION OF FERROSILICON CONTAINING 30 PER CENT SILICON FROM IRON TURNINGS.

In the calculations following, relative to producing ferrosilicon containing 30 per cent silicon from iron turnings, the assumptions made in the ore are as follows, the same as for the production of 30 per cent ferrosilicon using iron ore, except that in this case wrought iron or steel turnings are the source of iron:

		Calories required.
Reduction.		
300 kg. Si from SiO_2	300×6,428	1,928,400
Heating.		
700 kg. Fe to 1,400° C	700×1,400×0.2	196,000
300 kg. Si to 1,400° C	300×1,400×0.25	105,000
258 kg. C to 1,400° C	258×1,400×0.5	180,600
Total		2,410,000
Amount of heat supplied:		
By combustion of 258 kg. C	258×2,430	626,940
By the electric current		1,783,060
Total		2,410,000

Therefore the theoretical amount of electrical energy necessary for the production of 30 per cent ferrosilicon from iron turnings and quartz is the result of dividing 1,783,060 by 857, or 2,080 kilowatt-hours per metric ton, or 2,116 kilowatt-hours (0.24 kilowatt-year) per long ton.

From these figures it is evident that the production of 30 per cent ferrosilicon in the electric furnace when iron turnings are used requires only 68 per cent of the energy necessary with the use of iron ore.

FIFTY PER CENT FERROSILICON.

Analogous to the case of a 30 per cent ferrosilicon, with a 50 per cent product the power consumption with iron ore is 3,945 kilowatt-hours per metric ton, or 4,010 kilowatt-hours (0.46 kilowatt-year) per long ton. If iron turnings are used instead of iron ore the power consumption per ton of 50 per cent ferrosilicon made is 3,245 kilowatt-hours per metric ton, or 3,300 kilowatt-hours (0.38 kilowatt year) per long ton.

In making 50 per cent ferrosilicon, the saving in energy is not so great by using iron turnings instead of iron ore as in making the 30 per cent product because of the smaller amount of iron necessary in the charge. In making the 50 per cent alloy the energy consumption with turnings is 82 per cent of that with iron ore.

MANUFACTURE OF FERROSILICON IN THE BLAST FURNACE.

Ferrosilicon of less than 20 per cent silicon is made in the blast furnace, whereas the electric furnace is used for all the grades containing a higher percentage. The grades made in the blast furnace contain 10 to 20 per cent silicon, most of them containing less than 15 per cent silicon. Higher grades can not be produced in the blast furnace because of the impossibility of obtaining a high enough temperature. The wear on the furnace lining is great, and in order to maintain the high temperature necessary, a large quantity of coke is employed. As in the electric furnace, the silicon is reduced by solid carbon. Reduction is said to be more easy if the slag is low in lime and high in alumina—probably because the silicon does not have as strong an affinity for alumina as for lime. The charge used in the blast furnace may consist of siliceous iron ore, hammer scale, and coke, a hot blast being used. Gin gives as a charge: turnings 1,000 parts, quartz 410 parts, and coke 940 parts.[a]

In small furnaces the production is 30 to 40 tons per day, and with the large furnaces 80 to 100 tons per day. The blast-furnace operation of making ferrosilicon is similar to making pig iron, except that, owing to the highly siliceous slags, the steady operation of the furnace is more difficult. A small amount of blast-furnace ferrosilicon is imported, but most of it is produced here.

MANUFACTURE OF FERROSILICON IN THE ELECTRIC FURNACE.

RAW MATERIALS USED.

There are two general kinds of charge used in the manufacture of ferrosilicon in the electric furnace. The charge may consist of wrought iron, cast iron or steel turnings, quartz or sand, and charcoal, coal, or coke; or siliceous iron ore, quartz or sand, and charcoal, coal, or coke may be used. The choice of the source of iron depends chiefly on the material available. Iron in the form of turnings of some sort is more commonly used than iron ore, because, as has already been mentioned, it consumes much less power—68 per cent of the amount used for a 30 per cent alloy with iron ore, and 82 per cent for the 50 per cent product. The operation of a ferrosilicon furnace operating on turnings is much steadier and requires less attention because there is not as much slag formed as in the ore process. The purer the raw materials the purer is the product obtained. For this reason wrought iron or steel turnings are preferable to cast-iron borings and are used by most works. At the Girod plant, at Ugine, the average composition of the iron turnings used is 0.4 to 0.5 per cent carbon, 0.15 to 0.25 per cent silicon, 0.5 to 0.7 per cent manganese, 0.6 to 0.9 per cent sulphur, and 0.08 to 0.10 per cent phosphorus. Cast-iron turnings contain as high as 0.5 to 0.8 per cent phosphorus. At works at Bozel, France, steel or wrought-iron turnings containing less than 0.3 per cent phosphorus are used. Another French company, at Livet, uses steel turnings containing less than 0.10 per cent phosphorus.

---

[a] Conrad, W., and Pick, W., Die Herstellung von Hochprozentigem Ferrosilizium im elektrischen Ofen, 1909. Rev. de Métallurgie, vol. 9, 1912 p. 362.

The St. Marcel, France, works of the Société d'Industrie Electro-Chimiques La Voltes use steel shavings for 30 per cent ferrosilicon, and iron ore 95 per cent Fe_2O_3 for the 50 per cent grade. At Kanawha Falls, W. Va., iron ore is used in the production of 30 per cent ferrosilicon.[a] The ore contains 62.34 per cent iron, 7.93 per cent SiO_2, 0.09 per cent MgO, 0.72 per cent CaO, 0.4 per cent phosphorus, and a trace of sulphur. Gin in some experiments used a highly siliceous[b] iron ore containing 59.2 per cent Fe_2O_3, 2.1 per cent MnO, 24.6 per cent SiO_2 in producing a 50 per cent ferrosilicon.[b]

For the supplying of silicon in the charge, quartzite is preferable to sand because it is more nearly pure, and hence does not cause the formation of as much slag, which clogs the furnace. Also, the fine state of the sand seems to cause less regular operation of the furnace. The quartzite is usually crushed to about 2-inch size. At the Bozel plant mentioned above, the quartzite charged contains 95 per cent SiO_2, 4 per cent Al_2O_3, and traces of calcium and phosphorus. The Girod works use quartzite containing 92 per cent SiO_2 and traces of phosphorus and sulphur. At St. Marcel the quartzite has 98 per cent SiO_2, and a trace of MgO.

Whether charcoal, coke, or coal is used depends largely upon the cost of those materials in the district where a given plant is located. As the materials are used only as reducing agents and as, because of the absence of a shaft, no strength is necessary to support the charge in the ferrosilicon furnaces, the cheapest reducing material available is used. In France the works are all situated in the mountain districts where transportation costs are high, so that the local anthracite coal is largely employed. Most of such coal is rather high in ash, and when grades of ferrosilicon containing 75 per cent or more silicon are being manufactured it is customary to employ charcoal to avoid slag in the furnace. The slag increases the difficulties of operation considerably in the production of high-grade ferrosilicon and also increases the furnace impurities that would pass into the product. At the Girod plant in Ugine, coal guaranteed not to average more than 8 per cent ash or more than 0.005 per cent phosphorus or sulphur is used. The St. Marcel works employ gas coke for the production of 50 per cent grades, and a cheaper anthracite coal for the 25 per cent alloy or other low grades. A French company at Livet uses anthracite coal containing 7 per cent ash, 0.013 per cent phosphorus, 0.41 per cent sulphur, and no arsenic. At Bozel for the lower percentage alloys—50 per cent or less—anthracite coal containing 20 per cent ash is charged, but in the manufacture of the 80 per cent grade, charcoal is employed. In Norway and Sweden, where most of the ferrosilicon works are on tidewater or on a canal, anthracite coal of a high grade is generally used.

---

[a] Schoel, G. P., Manufacture of ferro-alloys in the electric furnace: Electrochem. Ind., vol. 2, 1904, p. 396.

[b] Schoel, G. P., loc cit.

In almost all plants the purest raw materials available are obtained for making ferrosilicon. As already mentioned, the introduction of slag-forming materials into the charge is thus prevented, and the presence of objectionable impurities such as phosphorus and sulphur in the product is avoided. With raw materials containing bases the silica intended for the product combines with the bases to form slag with such a high percentage of silica as to be very sticky, so that the pieces can be removed from the furnace only by fishing them out as they work to the surface around the electrode, although some of the slag may be tapped with the ferrosilicon. Owing to the strongly reducing nature of the process most of the phosphorus and sulphur charged goes into the metal. The sulphur, however, is slagged to a small extent.

CHARACTER OF FERROSILICON PLANTS.

Ferrosilicon plants are arranged and use the same general types of furnaces as have already been described. The Meraker, Ugine, and Livet works may be considered as typical. Conrad and Pick[a] have made a design of a works using 2,000 kilowatts, as shown in figures 55 and 56. There are two three-phase furnaces, each of 2,000 kilowatts capacity. Only one is operated at a time, the others being held in reserve. Each furnace has its own three transformers connected each to a phase in delta connection. The quartz is hauled up an incline to a crusher above, from which it falls into bins below. From the bins it is drawn into a car mixed with turnings and coal and raised on an elevator to the charging floor of the furnace. The general arrangement of the works is similar to that of other works. The total space occupied by the plant is 162,000 square feet distributed as follows:

	Square feet.
Electric furnaces	12,950
Transformers	6,470
Packing room	4,850
Setting up of electrodes	3,240
Crushing and mixing	6,470
Repair room	2,580
Coal room	12,950
Turnings store	3,240
Quartz store	32,400
Finished product room	6,470
Tool room	3,240
Office, laboratory	4,850
Yard, tracks	64,800
	162,000

---

[a] Conrad, W., and Pick, W., Die Herstellung von Hochprozentigen Ferrosilizium im elektrischen Ofen, 1909. Rev. de Métallurgie, vol. 9, 1912, p. 362.

PRACTICE.

METHOD OF CHARGING.

The raw materials are all thoroughly mixed before being charged into a ferrosilicon furnace. Charging may be from the tapping floor by a man shoveling the charge into the top of the furnace, or charging may be from a floor at the furnace top, the usual arrangement in modern works. In charging the material is placed at intervals around the electrodes, so that the top of the furnace never contains molten material except when some works up around the electrode. The electrode projects about 1 foot into the charge, and around the

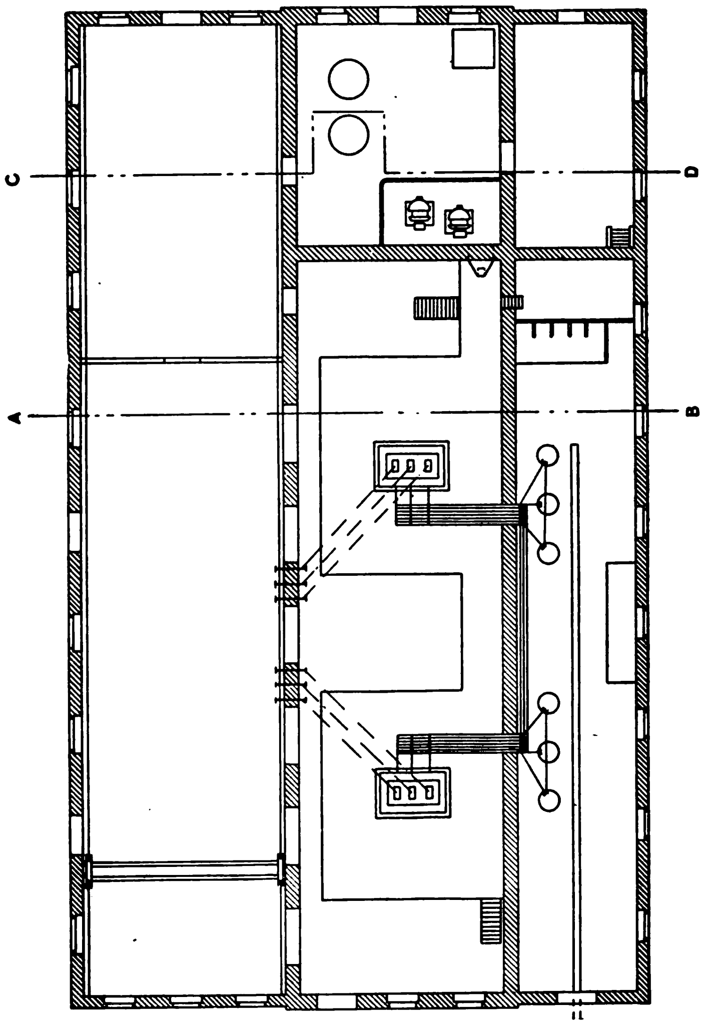
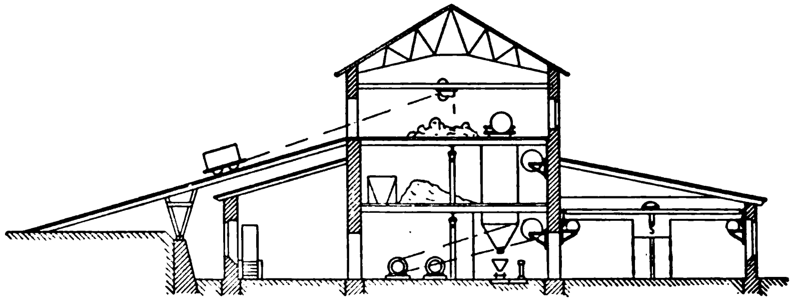
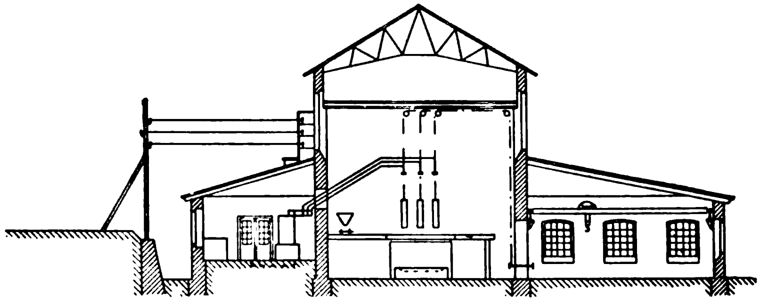


FIGURE 55.—Plan of ferrosilicon plant designed by Conrad and Pick.

end the material is molten and maintains a space of a fraction of an inch, so that the arc is maintained in the gas formed in the space. The arc is called a freeburning arc. By this method there is a lower power consumption than if the furnace is operated as a resistance furnace entirely. It is essential that the top of the furnace be covered with unmelted material, so as to cause less electrode and raw-material consumption. By operation with a covered bed of fusion, the silicon which is volatilized at a temperature higher than 2,000° C. is condensed in the upper part of the furnace. The unmelted charge also causes the coal consumption to be lower. In producing 50 per cent ferrosilicon in a furnace operated with an uncovered bed there were losses of 53.7 per cent of the quartz charged and 43.5 per cent coal by volatilization and oxidation,[a] as compared with 13.01 per cent quartz and 27.58 per cent coal in a modern furnace working with a cold top. As a result of this decrease of losses the efficiency is much increased. In the furnace operating with an uncovered bed and making 50 per cent alloy the power consumption was 7.25 kilowatt-hours per pound, or 16,350 kilowatt-hours per long ton. In operation with a covered bed the energy used was 3.16 kilowatt-hours per pound,



SECTION C-D



SECTION A-B

FIGURE 56.—Elevation of Conrad and Pick's ferrosilicon plant.

---

[a] Conrad, W., and Pick, W., Die Herstellung von Hochprozentigen Ferrosilizium im elektrischen Ofen, 1909. Rev. de Métallurgie, vol. 9, 1912, p. 362.

or 7,100 kilowatt-hours per long ton. With the furnace having an uncovered bed the efficiency was 25 per cent, and with the furnace having a covered bed the efficiency was 57.28 per cent. The low efficiency of the furnace with an uncovered bed was not due entirely to the system of operation, but was also due to the fact that the furnace was of 200 kilowatts capacity, as compared with a capacity of 1,500 kilowatts for the furnace with the covered bed. These examples also show the great strides made in the improvement of furnaces and of operating efficiency in the 10 years from 1900 to 1910, as the small furnace was one of the first to be built and the larger one of modern design.

TAPPING.

The furnace is tapped as seldom as possible. The necessity of tapping is indicated by the irregularity of the current as shown by the meters and the irregular blowing of gas out of the furnace, also, when the metal has been too close to the electrode there is an intermittent pounding sound. The shortest interval is about two hours. The length of the intervals depends upon the percentage of silicon in the product and the size of the furnace. In tapping, an iron rod is driven into the tap hole. If material with a high percentage of silicon is being made, it is sometimes necessary to attach the rod to the circuit and burn out the hole with an arc. The tap hole is plugged with fine clay or some similar refractory material.

A furnace operating steadily in making ferrosilicon has white fumes of silicon passing off at the top with carbon monoxide burning to dioxide around the electrodes. In some laboratory experiments by the writer, the condensed fumes from a ferrosilicon furnace contained 67.69 per cent SiO_2, 9.72 per cent Al_2O_3, 4.11 per cent FeO, 0.20 per cent MgO, and 1.90 per cent CaO, the rest probably being carbon.

CHANGING ELECTRODES.

When it is necessary to shut off the current in changing an electrode, if the shutdown be a long one, bars of iron are stuck down through the charge to make contact with the bottom or between the electrodes, so as to avoid difficulty in starting up. The molten charge is a good conductor, but is not so when solid.

Electrodes are replaced by simply swinging one in over the furnace to replace the holder and the burnt electrode removed. If the electrode has a tendency to rise in the furnace when a fixed voltage is being maintained by hand regulation of the electrode, quartz, a relatively poor conductor, is charged around the electrode, so that it becomes necessary to lower the electrode to maintain the current steadily. If the reverse is the case, coal is added to put in a good conductor for raising it.

SLAG FORMATION.

Because of the use of pure raw materials, comparatively little slag is formed in a ferrosilicon furnace. The slag formed consists of silicates of aluminum and lime or magnesia. They are very high in silica and rather infusible. The addition of more basic materials to make them fusible would do no good, because it would simply draw more silica from the charge and increase the total slag. As the percentage of silicon in the product increases, the specific gravity of the product decreases, so that it is difficult to obtain separation of slag and metal if the slag is sticky. In the manufacture of the 25 per cent alloy, slag is permissible, with a silicon content of 50 per cent, operation is difficult and with higher percentages is impossible if slag is present. As a rule, these slags are so thick that they are not tapped but boil up around the electrode and are removed there. The results of some analyses[a] are as follows:

	Per cent.	Per cent.	Per cent.
SiO_2	68.86	67.60	79.25
Al_2O_3	13.80	19.63	9.04
CaO	26.40	17.00	19.17
Fe_2O_3	1.96	1.02	3.50

The ferrosilicon is tapped into cars lined with sand or carbon. It is dumped to cool and broken into small pieces with hammers and weights. In tapping, iron must be kept away from the molten ferrosilicon as in the molten condition it dissolves iron readily. The product is usually packed in 100-kg. (220-pound) iron drums or in kegs.

RESULTS OF EARLY OPERATIONS.

In the early operations there was much excess raw material charged for the amount of product produced. In a small 200-kw. furnace of the old design, the following charges were made:[b] Twenty-five per cent product—40 parts quartz, 40 parts iron, 20 parts of anthracite; 50 per cent product—58 parts quartz, 13 parts iron, 29 parts anthracite; 70 per cent product—66 parts quartz, and 34 parts anthracite. The coal contained 20.71 per cent ash (2 to 3 per cent SiO_2), 71.29 per cent carbon, 1.08 per cent hydrogen, 1.11 per cent water, and 0.48 per cent sulphur. The turnings had 98 per cent iron. The quartz was 98.5 per cent SiO_2, and 0.5 per cent Fe_2O_3. For a 50 per cent ferrosilicon the following charge was used in an 1,800-kw. modern furnace and may be considered as representative practice: Fifty-four parts of quartz, 20 parts of iron turnings, 30 parts of charcoal. The quartz contained 95 per cent SiO_2 and 3.9 per cent Fe_2O_3; the turnings, 98.5 per cent iron; and the charcoal, 71.9 per cent carbon and 4 per cent ash.

---

[a] Conrad, W., and Pick, W., Die Herstellung von Hochprozentigen Ferrosilizium in elektrischen Ofen, 1909. Rev. de Métallurgie, vol. 9, 1912, p. 362.

[b] Conrad, W., and Pick, W., Loc. cit.

POWER CONSUMPTION.

The power consumption with this charge was 7,100 kilowatt-hours per long ton of 50 per cent ferrosilicon. Of the total energy 57.28 per cent was usefully used, 8.61 per cent was used in volatilizing silicon, and 0.23 per cent in volatilizing iron, and 33.88 per cent was lost by induction, radiation, and other losses. The electrode consumption during a month of steady operation averaged 84 pounds per long ton of 50 per cent product. Amorphous-carbon electrodes were used.

When iron turnings are used, the power consumption of a modern furnace of 750 kilowatts or more capacity is 6,800 to 8,000 kilowatt-hours per ton of 50 per cent ferrosilicon, and about 3,500 to 4,000 kilowatt-hours for the 25 to 30 per cent grade. As has already been noted in the discussion of the theory of power consumption, the power consumption is considerably higher if iron ore is used instead of turnings. With the ore mentioned on page 165, one company made 28 per cent ferrosilicon with a power consumption of 5,930 kilowatt-hours per ton.[a]

Louis[b] estimates the power consumption in the production of various grades of ferrosilicon, as shown in the table below, the figures being based on a 7,500-kw. plant and 750-kw. units:

Power consumption in ferrosilicon manufacture.

Raw materials.	Silicon in product.	Power consumption per pound.	Power consumption.	
	Per cent.	*Kilowatt-hours.*	*Kilowatt-hours.*	*Kilowatt-years.*
Quartzite, coke, iron turnings	25	1.82	4,080	0.46
Do	50	3.64	8,160	.92
Do	75	5.46	12,240	1.38
Slag and coke	25	1.82	4,080	.46
Slag, charcoal, sand	30	2.18	4,890	.56
Do	35	2.54	5,600	.64
Do	50	3.64	8,160	.92
Quartz, iron ore, coke, or anthracite	25	2.18	4,890	.56
Do	50	4.36	9,780	1.12
Enrichment of 25 per cent	50	4.36	9,780	1.12

WORKMEN REQUIRED.

A small furnace of 200 to 300 kw. requires one man for charging. Two men for six furnaces can perform the remaining duties, such as tapping and mixing charges, the total number necessary for six furnaces, being eight men. A large furnace of 2,000 to 3,000 kw. can be entirely operated by five men.

---

[a] Schoel, G. P., Manufacture of ferro-alloys in the electric furnace: Electrochem. Ind., vol. 2, 1904, p. 396.

[b] Louis, J., La fabrication des ferrosilicium au four electrique: Jour. du Four Electrique et de Lumière, Oct. 1, 1910, p. 415.

PRODUCTS.

Electric-furnace ferrosilicon is produced in four grades, classified according to silicon content, which is as follows for each grade:

Twenty-five to thirty per cent, 45 to 50 per cent, 75 to 80 per cent, and 90 to 95 per cent. The selling of these products is based entirely upon the silicon content, because the carbon content, owing to its usual low percentage, has no effect upon the price, as in other alloys. The current prices for the various grades are given in the table on page 140. Below are given the results of analyses of the four grades of electric-furnace ferrosilicon:

Results of analyses of four grades of ferrosilicon.[a]

Constituent.	Silicon content.			
	25 to 30 per cent.	45 to 50 per cent.	75 to 80 per cent.	90 to 95 per cent.
Silicon	30.50	49.50	78.00	88.50
Iron	68.00	49.00	20.00	9.30
Manganese	.35	.30	.25	.15
Aluminum	.10	.15	.10	.15
Magnesium	.10	.15	.30	.30
Carbon	.35	.30	.30	.25
Sulphur	.02	.015	.015	.015
Phosphorus	.04	.03	.03	.03

[a] Girod, P., Studies on the electrometallurgy of ferro-alloys and steels: Trans. Faraday Soc., vol. 6, 1911, p. 172.

In spite of the agitation against the manufacture of ferrosilicon containing between 38 and 65 per cent silicon because of the poisonous gases that are claimed to be given off, this grade is the one most largely made. Moreover, many persons believe that the gases can be eliminated if the ferrosilicon is made from pure materials.

PACKING AND TRANSPORTATION OF FERROSILICON.

Details on the packing of ferrosilicon in Sweden have recently been obtained by the Department of Labor.[a] The Gullspangs Elektrokemiska Aktiebalag use iron-bound wooden cases in two sizes, one for the 50 per cent product containing 130 kilograms (287 pounds), and one for the 75 per cent product containing 160 kilograms (353 pounds). The cases are unlined but are made of rabbeted boards. Recently the practice of packing the ferrosilicon in sheet-metal cylinders or drums containing 170 kilograms (375 pounds) was begun. The drums have four holes of about ¼-inch diameter in the top to prevent excessive gas pressure.

The Aktiebolaget Heroults Elektriska Stal until recently packed ferrosilicon in old wooden oil barrels. Now the company has adopted sheet-iron barrels with wooden heads. The barrels hold 300 kilograms (660 pounds).

---

[a] Anon., Packing and transport of ferrosilicon in Sweden: Met. and Chem. Eng., vol. 11, 1913, p. 87.

The regulations for transportation differ widely. In Germany water-tight packing is required. As a result, ferrosilicon is packed in barrels that are both water and gas tight. Some English railroads require that each package must have three 1-inch holes to permit the escape of gases. For safe transportation uniform regulations should be enforced by all countries.

COST OF MANUFACTURE.

The cost of manufacture of ferrosilicon depends more upon the price of electric power than upon any other item. This is because of the large amount of power necessary and the low cost of the raw materials composing the charge. Consequently a large part of the electric-furnace ferrosilicon used in the United States is imported from Europe and Canada. Of plants engaged in the manufacture of ferrosilicon the writer found none in which the power cost was over $20 per kilowatt-year and the average was about $13 per kilowatt-year.

An estimate of the cost of production of 50 per cent ferrosilicon is given in the table below. The calculations are on the basis of two 2,000-kilowatt furnaces, one operating and the other kept in reserve. The Norwegian plant is within 60 miles, the French plant within 200 miles, and the American works assumed to be within 100 miles of seaboard. Labor conditions are considered to be as found in the various countries.

Cost of production of 50 per cent ferrosilicon per ton (2,240 pounds).

Item.	Norway.		France.		United States.	
	Cost of unit.	Total cost.	Cost of unit.	Total cost.	Cost of unit.	Total cost.
1,170 pounds of iron	$14.00	$7.30	$14.00	$7.30	$8.00	$4.17
2,750 pounds of quartz	2.00	2.46	2.00	2.46	2.00	2.46
1,470 pounds of coal	8.00	5.30	6.00	3.95	5.00	3.30
50 pounds of electrodes	.04	2.00	.03	1.50	.04	2.00
0.8 kilowatt-year	8.30	6.62	18.66	15.00	26.66	21.30
Labor, salaries	[a]1	10.00	[a].80	8.00	[a]1.50	15.00
Repairs and maintenance		5.00		5.00		5.00
Amortization and depreciation 5 per cent each		2.00		2.00		2.00
Interest on $50,000 at 6 per cent		1.20		1.20		1.20
General and packing		4.00		4.00		4.00
Total		45.88		50.41		60.43

[a] Minimum for eight hours.

The electrode consumption is based upon the use of electrodes threaded for continuous feeding, a practice not now universally followed in ferro-alloy plants. The figures indicate that it costs $14.55

or 31.7 per cent more to manufacture 50 per cent ferrosilicon in the United States than in Norway. This difference may be considered as due largely to the price of power. The difference in the total cost of power in Norway and the United States for a ton of 50 per cent ferrosilicon is $14.68 per ton. Labor is also lower, but this is offset by the higher cost of raw materials abroad. The duty on ferrosilicon under the Underwood bill is 15 per cent ad valorem. The selling price of 50 per cent ferrosilicon f. o. b. Pittsburgh, Pa., is $70 to $75 per long ton.

USES.

The chief use for ferrosilicon is for the deoxidation of steel by the formation of silica or silicates with any free oxygen or oxides, the silica or silicates thus formed passing into the slag. A considerable amount is used for making fixed additions to steel. The grade containing 25 to 30 per cent silicon is used as a substitute for blast-furnace grades containing 10 to 12 per cent silicon. It is especially useful for direct addition to the open-hearth furnace, the cupola, or the converter, but may be added in the ladle. It is compact, in large pieces, and of sufficient specific gravity to sink readily in the bath. It reacts more energetically than does the alloy with the lower percentage of silicon and the quantities employed need not be so large. This grade is used chiefly for fixed additions of silicon.

Ferrosilicon that has 45 to 50 per cent silicon is particularly employed for deoxidation. It reacts like the 25 to 30 per cent alloy but more energetically, and is used when the greater specific gravity of the latter is not essential. It has a lower fusion point than the lower grade. It is subject to disintegration and is the only grade from which poisonous gases have been known to emanate. It is used in greater quantity than any of the other grades.

The grade containing 75 per cent silicon is employed for additions to ordinary castings. It can be used to modify a casting so as to obtain either a white or a gray casting by addition to the casting ladle. For a fixed addition in the production of silicon steels, such as transformer steel, 75 to 90 per cent ferrosilicon is employed.

Hadfield[a] developed silicon steel containing 1 to 5 per cent silicon, but the usual grade contains 2.75 per cent silicon with the smallest possible amounts of carbon, manganese, and other impurities. After a double-heating treatment this steel has a higher magnetic permeability than the purest iron, but also, as is characteristic of silicon steels, has a high electrical resistance. As a result of its high permeability, it has a low hysteresis loss, and is the most desirable material known for use in electrical generating machinery.

---

[a] Stoughton, B., The metallurgy of iron and steel, 1912, p. 406.

ALLOYS OF IRON AND SILICON WITH OTHER ELEMENTS.

For the use of foundries several alloys have been manufactured, such as ferrosilicomanganese-aluminum, ferrosilico-aluminum, and silicocalcium-aluminum. These alloys are intended for use as rapid deoxidizing and refining agents, and form easily fusible silicate slags of the other elements, which rise to the surface of the bath, as they are of low specific gravity. These alloys are too expensive for use in the large-scale production of ordinary steel.

Ferrosilicomanganese-aluminum is made in two grades, one containing 18 to 20 per cent silicon, 18 to 22 per cent manganese, and 9 to 12 per cent aluminum; and the other containing 9 to 11 per cent silicon, 9 to 11 per cent manganese, and 4.5 to 6 per cent aluminum, the rest in both grades being iron and carbon. The alloy is made by melting ferrosilicon-manganese and aluminum together. It is added in the ladle or molds, or in the furnace itself. It is used largely for cast steel, when the steel is cast directly into molds.

Another similar alloy is ferrosilico-aluminum, containing about 45 per cent silicon and 12 to 15 per cent aluminum, the rest being iron and carbon. It is made by alloying ferrosilicon and aluminum in the electric furnace. This alloy is intended for deoxidizing purposes. It is added in the electric steel furnace just after removal of the oxidizing slag. The alloy is in powder form and is also used in the tapping ladle for removing oxides. Sometimes it is added to the ingot molds. The electric furnace is the only furnace to which it is added for the manufacture of steel, because in the open hearth or converter there is great loss of the alloy. Ferrosilico-aluminum has not the reducing power of aluminum, but it is sufficient for the removal of most oxides.

Ferrosilicocalcium-aluminum is an electric-furnace product containing 50 to 55 per cent silicon, 18 to 22 per cent calcium, 12 to 15 per cent iron, 4 to 5 per cent aluminum, 1 to 1.25 per cent carbon, 0.35 per cent magnesium, 0.22 per cent manganese, 0.075 per cent sulphur and 0.03 per cent phosphorus. It is a strong deoxidizer and desulphurizer, and gives highly fluid slags. It is added in the electric furnace after the removal of the oxidizing slag. It can be added in the casting ladles, crucibles, or molds. Because of its high cost, its use is restricted to the manufacture of high-class steels.

FERROTITANIUM.

Ferrotitanium has been developed for use in steel manufacture since the introduction of the electric furnace for ferro-alloy production in 1900. In 1892 Rossi obtained a patent on the reduction of titaniferous ores in the blast furnace. Later he attempted to make a ferrotitanium in the blast furnace and crucible but could not obtain a product with a high percentage of titanium. Subsequent experimental work in the electric furnace resulted in the commercial establishment of the manufacture of ferrotitanium for steel making. Foreign manufacturers of ferro-alloys produced ferrotitanium on a small scale in the electric furnace. A considerable amount is made by the Goldschmidt thermit process. This grade is carbon free but contains as high as 5 per cent of aluminum, and is more expensive than the electric-furnace product.

All ferrotitanium now produced is manufactured either by reduction of ores with carbon in the electric furnace or by the Goldschmidt thermit process, most of it being made in the electric furnace. No other process gives a high enough temperature, 2,000° C., or over, for reduction of titanium from the oxide. In Rossi's first patent [a] on ferrotitanium, he specifies the reduction of titaniferous ores and rutile with carbon in an electric-resistance furnace to produce an alloy containing more than 5 per cent titanium and some carbon. The reduction is performed over a bath of molten iron. Another patent, [b] granted the same date, covers the use of titaniferous slag in the same manner. In 1900 he procured a patent[c] on the reduction of titanium ores by the addition of ores to a bath of molten reducing metal, such as aluminum, in the electric furnace. In 1901 Rossi [d] was granted a patent on a process for the concentration of titanium in slag by reducing the iron and silicon of a titaniferous ore with carbon at a temperature lower than the reducing point of titanium oxide.

Ferrotitanium is manufactured commercially at one plant in a Siemen's type of electric furnace of about 500 kw. capacity. A molten bath of iron from scrap iron or steel is first formed in the bottom of the furnace. Titaniferous ore, titaniferous slag, or rutile, is then mixed with carbon in the proper proportion, charged on the molten bath, and reduced in the arc. The product is tapped off and broken up for packing. If the slag is high in titanium it is run back through the furnace. The titaniferous ore contains 34.36 per cent TiO_2, 50.53 per cent FeO, 4.14 per cent SiO_2, and 2.20 per cent Al_2O_3. The product obtained from this reduction without any refining contains 10 to 15 per cent titanium, 5 to 8 per cent carbon, and 0.35 to 1 per cent silicon. By refining this alloy, with rutile as a decarburizer, an alloy is made that has 10 to 15 per cent titanium, less than 1.0 per cent carbon, and 0.35 to 1 per cent silicon. In a later patent,[e] in order to reduce the volatization loss of titanium, Rossi specifies the charging of lime on the molten iron bath, followed by a charge of titanic acid, lime, and carbon, when reduction takes place according to the following reaction:

$$CaO+TiO_2+5C=CaC_2+Ti+3CO$$

---

[a] U. S. patent No. 609466, August 23, 1898.

[b] U. S. patent No. 609467, August 23, 1898.

[c] U. S. patent No. 648439, May 1, 1900.

[d] U. S. patent No. 668266, February 19, 1901.

[e] U. S. patent No. 1019528, March 5, 1912.

The titanium sinks through the lime slag to the iron, and the reducing cover of calcium carbide protects the bath from oxidation. Because of its cost rutile (TiO_2) is not so extensively used in the manufacture of ferrotitanium as a titaniferous ore. Rutile sells for $100 to $150 per short ton.

The presence of carbides in electric-furnace ferrotitanium have been claimed to prevent its ready solution in steel, so that it would not do the work of carbon-free ferrotitanium. However, there does not appear to be over 0.25 per cent of combined carbon in the alloy containing 9 per cent carbon. The remaining carbon is present as graphite and on addition of the ferrotitanium to the steel bath part of the carbon combines with the steel to form carbides and the rest rises to the surface and is lost in the slag.

Ferrotitanium is added to steel and cast-iron baths for the purpose of final deoxidation of the metal and its impurities, following the usual treatment for this object by means of manganese and silicon.[a] Titanium has a strong affinity for oxygen and also seems to cause occluded or oxidized substances in the steel bath to separate readily. The resulting iron or steel is tougher and stronger after treatment. The alloy is added in the ladle into which the product of either the open-hearth furnace or the converter is being poured. It should be added last after carburizing and other alloys have been used, or much will be wasted. Too much slag should not be present, as titanium acts energetically with the slag. Ferrotitanium should never be preheated before being added or used in conjunction with aluminum. Little ferrotitanium is used for fixed addition to steel.

ELECTRIC SMELTING OF TUNGSTEN ORES AND THE PRODUCTION OF FERROTUNGSTEN.

HISTORY.

Ferrotungsten with a low percentage of tungsten was made by Berthier in 1834. Caron studied iron tungsten alloys in 1868 and determined that the hardness increased the percentage of tungsten. In 1866 Biermann made some ferrotungsten from tungsten trioxide and iron in the crucible. This method was used up to the introduction of the electric furnace in 1900, since which time most of the ferrotungsten has been made in the electric furnace, although small quantities, containing less than 60 per cent tungsten, are still manufactured in the crucible. The crucible product is made by the reduction of tungsten trioxide with carbon. In electric-furnace methods raw ores or concentrates are reduced.

---

[a] Stoughton, B., The metallurgy of iron and steel, 1908, p. 169.

EXPERIMENTS OF STASSANO.

Stassano[a] conducted experiments on the manufacture of ferrotungsten from wolframite concentrates in a 75-kw. electric furnace, with charcoal as a reducing agent. The concentrates, charcoal, and lime were crushed and briquetted with a 25 per cent solution of sodium silicate as a binder. Theoretically the ferrotungsten should have contained 71.5 per cent tungsten, 20.6 per cent iron, 7.1 per cent manganese, and 1 per cent silicon. The results of Stassano's experiments are tabulated below:

Constituent of ore charged:	Per cent.
WO_3	69.8
SiO_2	2.0
FeO	20.5
MnO	7.3
S	.2
P	Trace.
Constituent of charge:	**Parts.**
Wolframite	1,000
Charcoal	190
Lime	40
Mn_2SiO_3	80

Composition of products of three experiments.

Constituent.	Proportion in experiment No. — 1	2	3
	Per cent.	*Per cent.*	*Per cent.*
W	58.00	65.66	69.76
C	2.40	2.062	2.50
Mn	3.192	3.50	3.60
Si	1.244	1.02	1.30
P	Trace.	Trace.	Trace.
S	Trace.	Trace.	Trace.
Kilowatt-hours per pound of product	2.73	2.95	3.90
Kilowatt-years per ton (2,000 pounds) of product	.62	.67	.78

The average energy consumption was 3 kilowatt-hours per pound, or 0.68 kilowatt-year per ton. These experiments showed the possibility of reducing wolframite with carbon in the electric furnace, but did not show where the loss in tungsten occurred. It is not apparent whether the low tungsten content was the result of slag losses or the presence in the furnace of some unnoted iron which diluted the alloy.

EXPERIMENTS WITH COLORADO FERBERITE.

In 1911 the writer performed some experiments on the reduction of ferberite with carbon to produce ferrotungsten in the electric furnace.[a] The furnace was one described herein in the discussion of the production of ferrochrome. Analyses of the coke and lime employed are given in the table on page 128. Pure calcium fluoride was used. The iron ore contained 94.9 per cent Fe_2O_3, 4.10 per cent SiO_2, 0.79 per cent CaO, 1.46 per cent Al_2O_3, 0.05 per cent P, and 0.03 per cent S. Ferberite concentrates from Boulder County, Colo,. of the following composition were obtained: 58.72 per cent WO_3 (46.6 per cent tungsten), 30.08 per cent FeO (23.4 per cent iron), 2.55 per cent MnO (0.84 per cent manganese), 4.86 per cent SiO_2, 3.46 per cent CaO, 0.34 per cent P, and 0.20 per cent S.

---

[a] Stassano, E., Treatment of iron and steel in the electric furnace. Electrochem. and Met. Ind., vol. 6, 1908, p. 315.

In each experiment a decarburizing slag of iron ore, lime, and fluorspar was added to the furnace when reduction of the charge had been completed and allowed to act for 10 to 20 minutes. It was tapped from the furnace with the ferrotungsten and the slag from reduction.

As shown in the table following, the alloys obtained, with two exceptions, were somewhat lower in tungsten than had been calculated. This was the result of three causes: First, the presence in the furnace of iron due to hanging of a previous run with iron ore; second, the loss of tungsten in the slag; and, third, the iron reduced from the decarburizing slag. The carbon content of all of the alloys was low for ferrotungsten, a condition clearly assisted considerably by the use of the decarburizing slag of iron oxide and lime. It was manifest that with a longer decarburization period the carbon in the alloy could have been reduced still further. The greater part of the manganese in the charge was either slagged or volatilized. The percentage of silicon was high in some of the products, but much lower when there was no iron ore in the charge. Phosphorus and sulphur were easily slagged in spite of a high percentage of both in the ore. The slags contained 4.66 to 8.64 per cent tungsten oxide (or 3.7 to 6.8 per cent tungsten), and ferrous oxide in about the same percentage.

The commercial ferrotungsten from the electric furnace contains 50 to 80 per cent tungsten and 0.5 to 4 per cent carbon.

During the experiments 32 pounds of ferrotungsten was made, or an extraction of 83.8 per cent. The electrode consumption for the two experiments in which it was determined averaged 150 pounds per ton. This figure would be considerably reduced in large-scale operations. The average energy consumption for the seven experiments was 3.46 kilowatt-hours per pound tapped, or 0.79 kilowatt-year per ton. The ferrotungsten was hard and brittle, and castings made from it were free from blowholes.

---

[a] Keeney, R. M., The production of steels and ferro-alloys directly from ore in the electric furnace; Iron and Steel Inst., Carnegie Scholarship Memoirs, vol. 4, 1912, p. 108.

Detailed results of the experiments are tabulated below:

Results of experiments on the production of ferrotungsten directly from ore.

Experiment No.	1	2	3	4	5	6	7
Charge:							
Ferberite .... pounds..	5.00	10.00	5.00	5.00	6.00	6.00	6.00
Hematite .... do....	1.50	3.00	1.50	1.50	....	....	....
Coke .... do....	1.25	3.00	1.37	1.52	1.12	1.12	1.12
Lime .... do....	.75	1.56	.90	.95	.75	.75	.75
Fluorspar .... do....	.062	1.24	.062	.062	.062	.062	.062
Refining slag:							
Hematite .... do....	.75	.75	.75	.75	.75	.75	.75
Lime .... do....	.20	.20	.20	.20	.20	.20	.20
Fluorspar .... do....	.044	.044	.044	.044	.044	.044	.044
Composition of alloy:							
Tungsten .... per cent..	38.74	49.64	41.39	43.35	42.19	37.50	59.01
Carbon .... do....	1.77	1.82	2.05	2.51	1.66	2.04	2.02
Manganese .... do....	.32	.16	.42	.38	.16	.33	.16
Silicon .... do....	.47	.31	.24	.44	.14	.07	.09
Phosphorus .... do....	.044	.046	.042	.048	.051	.054	.020
Sulphur .... do....	.032	.068	.089	.017	.014	.021	.015
Composition of slag:							
WO_3 .... do....	8.64	4.14	7.20	4.24	4.00	5.28	4.88
SiO_2 .... do....	30.12	31.10	31.00	31.40	30.40	29.28	29.64
CaO .... do....	21.30	37.00	30.00	24.60	28.00	21.10	29.30
MgO .... do....	16.60	12.00	19.60	26.64	24.48	23.64	18.80
FeO .... do....	12.60	12.00	5.84	4.52	5.84	5.10	6.87
Al_2O_3 .... do....	12.10	5.70	5.24	6.95	6.22	11.67	7.88
Wolfram in product, calculated percentage........	50.00	50.00	50.00	50.00	65.00	65.00	65.00
Carbon per pound W and Fe, pounds........	.202	.222	.222	.212	.214	.214	.214
Alloy calculated, pounds........	5.08	10.16	5.08	5.08	4.30	4.30	4.30
Alloy tapped, pounds........	2.00	8.78	5.62	2.20	6.50	2.20	4.62
Power consumption per pound tapped, kilowatt-hours........	4.76	2.63	2.00	5.78	1.86	5.25	1.96
Power consumption per ton tapped, kilowatt-years........	1.09	.60	.46	1.32	.42	1.20	.45

CONCLUSIONS.

Conclusions drawn from the experiments are as follows: First, ferrotungsten can be produced directly from ferberite in the electric furnace; second, by the use of a decarburizing slag before tapping the percentage of carbon in the alloy can be kept below 2 per cent; third, manganese, silicon, phosphorus, and sulphur do not enter the ferro-alloy in high percentages; fourth, the loss of tungsten in the slag need not be excessive; and fifth, the power consumption need not exceed 3.46 kilowatt-hours per pound of ferrotungsten tapped, or 0.79 kilowatt-year per ton.

THEORY OF TUNGSTEN ALLOYS.

Several carbides and alloys of iron and tungsten have been isolated from ferrotungsten. Moissan[a] obtained W_2C by fusing carbon and tungsten in the electric furnace; in the same manner Williams[a] found WC. Williams obtained $2Fe_3C.3W_2C$ by the reduction of tungsten trioxide with carbon in the electric furnace. Behrem found Fe_2W in ferrotungsten containing 50 per cent tungsten. Carnot and Goutal isolated Fe_3W. Benneville isolated Fe_4W.

---

[a] Guillet, L., Étude industriel des alliages métallique, p. 425.

Bierman found Fe_3W_2C. The double carbide is not of constant composition. W_2Si_3 is known to exist, and the compound WSi is believed to exist. W_2Si_3 was obtained by Moissan synthetically in the electric furnace. The carbides W_2C and WC are both iron gray and very hard. WC fuses with difficulty.

REACTIONS.

Ferrotungsten can be made by reduction of wolframite, ferberite, or scheelite with aluminum, silicon, or carbon. Rossi[a] reduced ferberite with aluminum in a Siemens type of electric furnace. An alloy containing 75.9 per cent tungsten, 21.4 per cent iron, 1.6 per cent silicon, 0.08 per cent sulphur, and 0.9 per cent carbon was made from concentrates containing 69.8 per cent WO_3, 20.25 per cent FeO, and 5.04 per cent SiO_2. The reaction used is as follows:

$$3Fe_2WO_4+8Al=3Fe_2W+4Al_2O_3$$

For the reduction of 100 parts of 62.3 per cent tungsten ferrotungsten from 122 parts of ferberite 24.2 parts of aluminum is necessary.

Gin has produced ferrotungsten by the reduction of scheelite with a bath of 20 per cent ferrosilicon in the electric furnace according to the following reaction:

$$3CaWO_4+4Fe_2Si=(2Fe_2W+Fe_3W)+3CaSiO_3+FeSiO_3$$

The most common method for the production of ferrotungsten is by the reduction of ferberite, wolframite, or scheelite concentrates in the electric furnace with carbon as a reducing agent, followed by a subsequent decarburization and refining. Wolframite or ferberite is readily reduced in this manner, but there is difficulty in the reduction of scheelite. Ferberite is wolframite [$(FeMn)WO_4$], in which the manganese is replaced by iron so as to give $(FeFe)WO_4$. Reduction occurs with carbon according to the following reaction:

$$Fe_2WO_4+4C=Fe_2W+4CO$$

Theoretically the product contains 62.3 per cent tungsten. For the reduction of 100 parts of this alloy from 122 parts of ferberite 16.2 parts of carbon is necessary.

Scheelite is now smelted by one company with sulphide of iron and carbon in the electric furnace.[b] Lime is also added to flux the silica. The following reaction takes place:

$$CaWO_4+FeS+4C=FeW+CaS+4CO$$

The product is said to be a ferrotungsten containing little carbon.

After much experimental work on a large scale, it seems that reduction with carbon followed by decarburization with iron ore or tungsten concentrates is the cheapest and most efficient method of making ferrotungsten in the electric furnace. Aluminum is expensive and goes into the alloy to a certain extent, as also does silicon.

---

[a] Rossi, A. J., Ferro-alloys: Mineral Industry, 1903, p. 693.

[b] Editorial, Electric production of ferrotungsten: Eng. and Min. Jour., January 20, vol. 93, 1912, p. 173.

Ferrotungsten may be decarburized by covering the fused metal in the electric furnace with hammer scale, when the following reaction takes place:

$$Fe_6O_7+7W_2C=6FeW_2+W_2+7CO.$$[a]

The reaction is not strictly quantitative because there is always formed some ferrous tungstate.

It is possible to make ferrotungsten containing 80 per cent tungsten and less than 0.5 per cent carbon by the following reaction:

$$Fe_6O_7+3W_2C=5FeW+FeWO_4+3CO$$

Ferberite or wolframite may be used instead of hammer scale. Slags high in tungsten are run through the reducing furnace again. By the above method carbon can not be reduced below 0.3 per cent in the alloy.

Ferrotungsten with less than 80 per cent tungsten can be made by adding metallic iron to the bath and decarburizing with iron oxide and hammer scale.

Alloys with as low a carbon content as 0.15 per cent can be made by use of the following reaction:

$$3W_2C+Fe_2O_3+2Fe=3CO+(3FeW_2+Fe).$$

Decarburizing with iron oxide has a tendency to cause loss of tungsten in the slag by the formation of tungstate of iron. This loss may be reduced somewhat by making the decarburizing slag rather acid when ferrous silicate is formed, according to the following reaction:

$$W_2C+Fe_2O_3+2SiO_2=W_2+2FeSiO_3+CO.$$

PROCESS OF MANUFACTURE.

Ferrotungsten is manufactured from ores in three ways, as follows: First, by direct reduction with carbon in a crucible; second, by reduction in an electric furnace by some reducing agent other than carbon; and third, by direct reduction with carbon in an electric furnace.

In manufacture by the crucible process concentrates are placed in a clay-lined crucible with the proper proportions of reducing agent and flux, and heated to a high temperature in a gas-fired furnace.[b]

---

[a] Gin, G., Molybdenum and tungsten: Trans. Am. Electrochem. Soc., vol. 13, 1908, p. 48.

[b] Pratt, S. R., Manufacture of metallic tungsten and ferrotungsten in the crucible: Eng. and Min. Jour., vol. 90, 1910, p. 959.

There is considerable wear on the crucible in this method. In making a 30 per cent tungsten alloy the crucible will last about three heats, but in making a 65 to 75 per cent product it lasts only one heat. Alloys with higher percentages of tungsten than this are not made in the crucible furnace.

In the electric-furnace process, ferberite, wolframite, hubuerite, or scheelite is reduced with carbon in an arc furnace. As with many expensive alloys, the process is generally an intermittent one; that is, the reduced charge is tapped from the furnace before another charge is added, or the charge is allowed to solidify and is chiseled out of the furnace. Sometimes a campaign of several days is made. The reduced alloy is either decarburized with refining slags in the same furnace or melted and refined later in another furnace. The furnaces used are similar in design to the ones described for ferrochrome production, but a more complete recovery is effected by the use of a tilting rather than a stationary furnace. Wolframite, ferberite, and scheelite are reduced easily in the electric furnace, most of the manganese being volatilized. Scheelite is more difficult to reduce and very sticky basic slags result. There is greater loss in its reduction, so that it does not command as high a price as the other ores, selling for about $1 per unit less. The product is tapped into molds, broken on cooling, and packed into kegs or boxes.

The largest producers of tungsten ores are Australia, Colorado, California, and Argentina. The standard concentrate contains 60 per cent tungsten trioxide (WO_3). The price varies from $5 to $8 per unit in the 60 per cent grade; that is, if the rate was $5, a 60 per cent concentrate would be worth $300 per short ton. The analysis of a typical Colorado ore, ferberite, has been given previously in a discussion of the author's experiments. A typical scheelite contains 69.50 per cent WO_3, 16.04 per cent CaO, 0.54 per cent FeO, 0.18 per cent MnO, 0.14 per cent P_2O_5, and 12.46 per cent SiO_2.

The results of analyses of typical ferrotungsten produced in the electric furnace are given below.

Results of analyses of typical ferrotungsten.

Analysis No.	1	2	
	Per cent.	*Per cent.*	*Per cent.*
Tungsten	73.0	78.5	83.0
Carbon	3.5	1.7	.6
Iron	19.0	18.5	15.5
Silicon	.4	.3	.4
Manganese	3.5	.4	.2
Calcium	Trace.	.1	.151
Arsenic	.4	.1	.10
Tin	.1	.05	.05
Sulphur	.05	.04	.04
Phosphorus	.03	.015	.015

USES.

Tungsten was first added to steel almost entirely in the form of a powder, manufactured chemically. The powder has now been replaced by ferrotungsten to such an extent that hundreds of tons of the latter is produced annually. It is claimed by ferrotungsten manufacturers that there is less loss by oxidation and a more uniform solution of tungsten in the steel if ferrotungsten is used. The powder manufacturers claim that the alloy is not uniform in composition. There is such diversity of opinion in this respect that it is difficult to state which is the better, but the production of ferrotungsten is increasing.

Ferrotungsten is used for the addition of tungsten in the manufacture of self-hardening or high-speed steels. It is added in the furnace or in the crucible.

Most self-hardening steel contains 4 to 12 per cent of tungsten, with 2 to 4 per cent of manganese and 1.5 to 2.5 per cent of carbon. It is hard without being subjected to any heat treatment or any other process for making it so. It can not be made soft, or amended by any process known at present. All of the self-hardening steels are nonmagnetic. They are used for making tools. The cutting speed of tools made from self-hardening steel is not much, if any, greater than that of tools made from ordinary carbon tool steel, but the former take deep cuts and last longer without grinding. The 2 to 4 per cent manganese can be replaced by 1 to 2 per cent of chromium. The 12 per cent molybdenum can be replaced by 4 to 8 per cent molybdenum.

High-speed steels contain as much as 24 per cent tungsten and 0.40 to 0.80 per cent carbon. These steels do not lose their temper or toughness at a red heat, so that they are adapted for tools to be used for high-speed cutting. In the steel for cutting tools the tungsten may be replaced by one-half as much molybdenum. In this way 6 to 15 per cent molybdenum is used. A little vanadium can be added with beneficial results.

For permanent magnets a steel containing 4 to 5 per cent of tungsten and 0.5 to 0.7 per cent of carbon, if heated to a red heat and quenched in water, will retain its magnetism better than ordinary hardened carbon steel.

ELECTRIC SMELTING OF VANADIUM ORES AND THE PRODUCTION OF FERROVANADIUM.

Most of the ferrovanadium made is produced by the thermit process, by reduction of the oxide V_2O_5 in a crucible with carbon, or by reduction of vanadate of iron with carbon in a crucible. In Europe some ferrovanadium is made by the reduction of the oxide, sulphide, or vanadate of iron with carbon in the electric furnace. The rgest source of vanadium is the Peru deposit of patronite, a sulphide of vanadium containing about 60 per cent sulphur and 20 per cent vanadium. In Colorado and Utah there are large deposits of low-grade carnotite, a uranium and vanadium oxide mineral. Another ore found there is roscoelite, which contains vanadium oxide, but no uranium. The patronite ore is first roasted and then reduced by the thermit process; or in the electric furnace it may be directly reduced with lime as a desulphurizing agent and carbon as a reducing agent. The other ores are treated by chemical or ore-dressing processes to obtain the vanadium as oxide or vanadate of iron, and are then reduced with carbon in a combustion or electric furnace or by the thermit method. With oxides the electric furnace method is similar to the production of ferrotungsten with carbon as a reducing agent. The sulphide reduction is similar to that of molybdenite with lime and carbon. In several patented methods silicon is used as a reducing agent in the electric furnace. The process as performed in the electric furnace has no novel features beyond those stated regarding chromium, tungsten, and molybdenum. Decarburization is with oxide of iron ore or oxide ore of vanadium. Vanadium is rather difficult to reduce, and as a result excess carbon is used which is absorbed up to about 6 per cent by the ferrovanadium. The electric furnace product is made in 50 per cent and 25 per cent grades, with carbon varying from 1 to 4 per cent. Below are the results of analyses of these grades:

Results of analyses of ferrovanadium.

Constituent.	Grade with 50 per cent vanadium.	Grade with 25 to 30 per cent vanadium.
Vanadium	55.00	34.10
Iron	40.00	64.10
Carbon	4.00	1.42
Silicon	.30	.12
Aluminum	.10	.12
Manganese	.30	.12
Sulphur	.03	.03
Phosphorus	.04	.009

Vanadium acts like titanium as a cleanser and deoxidizer of a steel bath, and is also used to add as much as about 0.35 per cent vanadium to the steel itself. It is used after ferrosilicon and ferromanganese have been added, so as to prevent loss, and causes deoxidation beyond the point obtained by these alloys. It melts without much difficulty and attacks the oxides present. Incorporated in the steel in proportions up to 0.30 per cent it toughens and adds a great tensile strength to the steel.

GLOSSARY.

Inasmuch as this bulletin has been prepared for the purpose of giving information to those who are not familiar with electrical work, the following glossary, taken mainly from Kent's "Mechanical Engineer's Pocket-Book" (eighth edition) has been prepared:

UNITS USED IN ELECTRICAL CALCULATIONS.

Ampere.—The unit of current strength, or rate of flow, represented by I.

Volt.—The unit of electromotive force, electrical pressure, or difference of potential, represented by E.

Ohm.—The unit of resistance, represented by R.

Coulomb (or ampere-second).—The unit of quantity, Q.

Ampere-hour.—3,600 coulombs, Q'.

Joule (volt-coulomb).—The unit of energy or work, W.

Watt (ampere-volt, or volt-ampere).—The unit of power, P.

Farad.—The unit of capacity, represented by C.

Henry.—The unit of inductance, represented by L.

If letters are used to represent the units, the relations between them may be expressed by the following formulas, in which t represents 1 second and T 1 hour:

$$I=\frac{E}{R},\ Q=It,\ Q'=IT,\ C=\frac{Q}{E},\ W=QE,\ P=IE.$$

As these relations contain no coefficient other than unity, the letters may represent any quantities given in terms of those units. For example, if E represents the number of volts of electromotive force, and R the number of ohms of resistance in a circuit, then their ratio, $E \div R$, will give the number of amperes of current strength in that circuit.

The above six formulas can be combined by substitution or elimination, so as to give the relations between any of the quantities. The most important of these are the following:

$$Q=\frac{E}{R}t,\ C=\frac{I}{E}t,\ W=IEt=\frac{E^2}{R}t=I^2Rt=Pt$$

$$E=IR,\ R=\frac{E}{I},\ P=\frac{E^2}{R}=I^2R=\frac{W}{t}=\frac{QE}{t}.$$

RELATIONS OF VARIOUS UNITS.

1 ampere = 1 coulomb per second.
1 volt-ampere = 1 watt = 1 volt-coulomb per second.
1 watt = { 0.7373 foot-pound per second.
0.0009477 heat unit per second (F).
1/746 of 1 horsepower.
1 joule = { 0.7373 foot-pound.
Work done by 1 watt in 1 second.
0.0009477 heat unit.
1 British thermal unit = 1055.2 joules.
1 kilowatt, or 1,000 watts = 1,000/746, or 1.3405 horsepower.
1 kilowatt-hour = 1.3405 horsepower-hours.
1,000 volt-ampere hours = 2,645,200 foot-pounds.
1 British Board of Trade unit = 3412 heat units.
1 horsepower = { 746 watts = 746 volt-amperes.
33,000 foot-pounds per minute.

The ohm, ampere, and volt are defined in terms of one another as follows: Ohm, the resistance of a conductor through which a current of 1 ampere will pass when the electromotive force is 1 volt. Ampere, the quantity of current that will flow through a resistance of 1 ohm when the electromotive force is 1 volt. Volt, the electromotive force required to cause a current of 1 ampere to flow through a resistance of 1 ohm.

Equivalent values of electrical and mechanical units.

Unit.	Equivalent value in other units.
1 kilowatt-hour.	1,000 watt hours. 1.34 horsepower-hours. 2,654,200 foot-pounds. 3,600,000 joules. 3,412 heat units. 367,000 kilogram-meters. 0.235 pound of carbon oxidized with perfect efficiency. 3.53 pounds of water evaporated from and at 212° F. 22.75 pounds of water raised from 62° to 212° F.
1 horsepower-hour.	0.746 kilowatt-hour. 1,980,000 foot-pounds. 2,545 heat units. 273,740 kilogram-meters. 0.175 pound of carbon oxidized with perfect efficiency. 2.64 pounds of water evaporated from and at 212° F. 17 pounds of water raised from 62° to 212° F.
1 kilowatt......	1,000 watts. 1.34 horsepower. 2,654,200 foot-pounds per hour. 44,240 foot-pounds per minute. 737.3 foot-pounds per second. 3,412 heat units per hour. 56.9 heat units per minute. 0.948 heat unit per second. 0.2275 pound of carbon oxidized per hour. 3.53 pounds of water evaporated per hour from and at 212° F.
1 horsepower...	746 watts. 0.746 kilowatt. 33,000 foot-pounds per minute. 550 foot-pounds per second. 2,545 heat units per hour. 42.4 heat units per minute. 0.707 heat unit per second. 0.175 pound of carbon oxidized per hour. 2.64 pounds of water evaporated per hour from and at 212° F.
1 joule........	1 watt second. 0.000000278 kilowatt-hour. 0.102 kilogram-meter. 0.0009477 heat unit. 0.7373 foot-pound.
1 foot-pound...	1.356 joules. 0.1383 kilogram-meter. 0.000000377 kilowatt-hour. 0.001285 heat units. 0.0000005 horsepower-hour.
1 watt..........	1 joule per second. 0.00134 horsepower. 3.412 heat units per hour. 0.7373 foot-pound per second. 0.0035 pound of water evaporated per hour. 44.24 foot-pounds per minute.
1 watt per square inch.	8.19 heat units per square foot per minute. 6,371 foot-pounds per square foot per minute. 0.193 horsepower per square foot.
1 heat unit.....	1,055 watt-seconds. 778.6 kilogram-meters. 0.000293 kilowatt-hour. 0.000393 horsepower-hour. 0.0000688 pound of carbon oxidized. 0.001036 pound of water evaporated from and at 212° F.
1 heat unit per square foot per minute.	0.122 watt per square inch. 0.0176 kilowatt per square foot. 0.0236 horsepower per square foot.
1 kilogram-meter.	7.233 foot-pounds. 0.00000365 horsepower-hour. 0.00000272 kilowatt-hour. 0.0093 heat unit.
1 pound of carbon oxidized with perfect efficiency.	14,544 heat units. 1.11 pounds of anthracite coal oxidized. 2.5 pounds of dry wood oxidized. 21 cubic feet of illuminating gas. 4.26 kilowatt-hours. 5.71 horsepower-hours. 11,315,000 foot-pounds. 15 pounds of water evaporated from and at 212° F.
1 pound of water evaporated from and at 212° F.	0.283 kilowatt-hour. 0.379 horsepower-hour. 965.7 heat units. 103,900 kilogram-meters. 1,019,000 joules. 751,300 foot-pounds. 0.0664 pound of carbon oxidized.

LAWS OF ELECTRICAL RESISTANCE.

The resistance, R, of any conductor varies directly as its length, l, and inversely as its section area, s, or $R \propto l \div s$.

If r = the resistance of a conductor 1 unit in length and 1 square unit in sectional area, $R = rl \div s$. The common unit of length for electrical calculations in English measure is the foot, and the unit of area of wires is the circular mil, which equals the area of a circle 0.001 inch in diameter. One mil-foot is equivalent to an object 1 foot long and 1 circular mil in cross section. Resistance of 1 mil-foot of soft copper wire at 51° F. = 10 international ohms.

Example.—What is the resistance of a wire 1,000 feet long and 0.1 inch in diameter?

0.1 inch in diameter = 10,000 circular mils.

$R = rl \div s = 10 \times 1{,}000 \div 10{,}000 = 1$ ohm.

Specific resistance, also called resistivity, is the resistance of a material of unit length and section as compared with the resistance of soft copper.

Conductivity is the reciprocal of specific resistance, or the relative conducting power compared with copper taken at 100.

Electrical conductivity of different metals and alloys.

Pure silver	100	Swedish iron	16
Pure copper	100	Pure Banca tin	15.45
Telegraphic siliceous bronze	98	Aluminum bronze (10 per cent)	12.6
Alloy of one-half copper and one-half silver	86.65	Siemens steel	12
Pure gold	78	Pure platinum	10.6
Silicide of copper, 4 per cent Si	75	Copper with 10 per cent nickel	10.6
Telephonic siliceous bronze	35	Pure lead	8.88
Pure zinc	29.9	Bronze with 20 per cent tin	8.4
Brass with 35 per cent zinc	21.5	Pure nickel	7.89
Phosphor tin	17.7	Phosphor bronze, 10 per cent tin	6.5
Alloy of one-half gold and one-half silver	16.12	Antimony	3.88

Conductivity of aluminum.—J. W. Richards (Jour. Franklin Inst., Mar., 1897) gives for hard-drawn aluminum of purity 98.5, 99, 99.5, and 99.75 per cent, respectively, a conductivity of 55, 59, 61, and 63 to 64 per cent, copper being 100 per cent. The Pittsburgh Reduction Co. claims that its purest aluminum has a conductivity of over 64.5 per cent. (Eng. News, Dec. 17, 1896.)

German silver.—The resistance of German silver depends on its composition. Matthiessen gives it as nearly 13 times that of copper, with a temperature coefficient of 0.0004433 per degree centigrade. Weston, however (Proc. Electrical Cong., 1893, p. 179), has found copper-nickel-zinc alloys (German silver) that had a resistance of nearly 28 times that of copper and a temperature coefficient of about one-half that given by Matthiessen.

Conductors and insulators in order of their value.

CONDUCTORS.

All metals.
Well-burned charcoal.
Graphite.
Acid solutions.
Saline solutions.
Metallic ores.
Animal fluids.
Living vegetable substances.
Moist earth.
Water.

INSULATORS (NONCONDUCTORS).

Dry air.
Shellac.
Paraffin.
Amber.
Resins.
Sulphur.
Wax.
Ebonite.
Gutta percha.
India rubber.
Silk.
Dry paper.
Parchment.
Dry leather.
Jet.
Glass.
Mica.
Porcelain.
Oils.

According to Culley, the resistance of distilled water is 6,754 million times as great as that of copper. Impurities in water decrease its resistance.

RESISTANCE VARIES WITH TEMPERATURE.

For every degree centigrade, the resistance of copper increases about 0.4 per cent, or for every degree Fahrenheit, 0.2222 per cent. Thus, a piece of copper wire having a resistance of 10 ohms at 32° would have a resistance of 11.11 ohms at 82° F.

The following table shows the amount of resistance of a few substances used for various electrical purposes by which 1 ohm is increased by a rise of temperature of 1° C.

Platinoid	0.00021	Gold, silver	0.00065
Platinum silver	.00031	Cast iron	.00080
German silver	.00044	Copper	.00400

OHM'S LAW.

This law expresses the relation between the three fundamental units of resistance, electrical pressure, and current. It is:

$$\text{Current}=\frac{\text{electrical pressure}}{\text{resistance}};\ I=\frac{E}{R};\ \text{whence } E=IR \text{ and } R=\frac{E}{I}.$$

In terms of the units of the three quantities,

$$\text{Amperes}=\frac{\text{volts}}{\text{ohms}};\ \text{volts}=\text{amperes}\times\text{ohms};\ \text{ohms}=\frac{\text{volts}}{\text{amperes}}.$$

EXAMPLES.

1. If the source has an effective electrical pressure of 100 volts, and the resistance is 2 ohms, what is the current?

$$I=\frac{E}{R}=\frac{100}{2}=50 \text{ amperes}$$

2. What pressure will give a current of 50 amperes through a resistance of 2 ohms?

$$E=IR=50\times2=100 \text{ volts.}$$

3. What resistance is required to obtain a current of 50 amperes when the pressure is 100 volts?

$$R=E\div I=100\div50=2 \text{ ohms.}$$

Ohm's law applies equally to a complete electrical circuit and to any part thereof.

HEAT GENERATED BY A CURRENT.

Joule's law shows that the heat developed in a conductor is directly proportional, first, to its resistance; second, to the square of the current strength; and, third, to the time during which the current flows, or $H=I^2Rt$. Since $I=E\div R$,

$$I^2Rt=\frac{E}{R}IRt=EIt=E\frac{Et}{R}=\frac{E^2t}{R}$$

Or, heat=current^2×resistance×time
=electromotive force×current×time
=electromotive force^2×time÷resistance
Q=quantity of electricity flowing=It, or $(Et\div R)$
$H=EQ$, or heat=electromotive force×quantity.

The electromotive force here is that causing the flow, or the difference in potential between the ends of the conductor.

The electrical unit of heat or "joule" equals 10^7 ergs, equals heat generated in 1 second by a current of 1 ampere flowing through a resistance of 1 ohm, equals 0.239 gram of water raised 1° C. $H=I^2Rt\times0.239$ gram calories$=I^2Rt\times0.0009478$ British thermal unit.

In electric lighting the energy of the current is converted into heat in the lamps. The resistance of the lamp is made great so that the required quantity of heat may be developed, while in the wire leading to and from the lamp the resistance is made as small as is commercially practicable, so that as little energy as possible may be wasted in heating the wire.

SELECTED BIBLIOGRAPHY.

BOOKS.

Ashcroft, E. A. Study of electrothermal and electrolytic industries. New York, 1909. Intended to supply information about all industrially successful electrochemical and electrometallurgical industries.

Borchers, W. Electric furnaces; the production of heat from electrical energy, and the construction of electric furnaces. Translated by H. G. Solomon, London, 1908.

Guillet, S. Étude industriel des alliages métallique. Paris.

Haanel, E. Report of commission appointed to investigate different electrothermic processes for smelting iron ores and making steel in Europe. Canada, Department of the Interior, Mines Branch, 1904.

——— Report on electric shaft furnace at Domnarfvet, Sweden. Canada, Department of the Interior, Mines Branch, 1909.

——— Recent advances in electric smelting. Bulletin No. 3, Canada, Department of the Interior, Mines Branch, 1910.

——— Report on experiments at Sault Sainte Marie, Ontario, under government auspices on smelting of Canadian iron ores by the electrothermic process. Canada, Department of the Interior, Mines Branch, 1907.

Havard, F. T. Refractories and furnaces. New York, 1912.

Ingalls, W. R. The metallurgy of zinc.

Kershaw, J. B. C. Electrometallurgy. London, 1908.

Minet, A. The production of aluminium and its industrial use. Translated with addition by L. Waldo, New York, 1905.

Moissan, H. The electric furnace. Translated by V. Lenher, 1904.

Neumann, B. Elektrometallurgie des Eisens, W. Knapp, Halle, Germany, 1907.

Robin, F. Traite de Metallographie. Paris, 1912.

Rodenhauser, W., and Schoenawa, I. Electric furnaces in the iron and steel industry. Translated by C. H. Vom Baur. 1913.

Stansfield, A. The electric furnace, its evolution, theory, and practice. New York, 1907.

Thompson, M. de Kay. Applied electrochemistry. New York, 1911.

Wright, J. Electric furnaces and their industrial applications. New York, 1904.

PUBLISHED PAPERS AND ARTICLES.

ALUMINUM.

Burgess, C. F., and Hambuechen, C. Some laboratory observations on aluminum. Electrochem. Ind., vol. 1, 1902, p. 165.

Engineering and Mining Journal. Electric reduction of aluminum. Vol. 93, 1912, p. 641.

Hambuechen, C. See Burgess, C. F.

Hutton, R. S., and Petavel, J. E. On direct reduction of alumina with carbon. Electrochem. and Met. Ind., vol. 6, 1908, p. 104.

Mineral Industry. Aluminum. Vol. 19, 1910, p. 18, vol. 20, 1911, p. 22.

Neumann, B., and Ollsen, H. Production of aluminium as a laboratory experiment. Met. and Chem. Eng., vol. 7, 1910, p. 185.

lsen, H. See Neumann, B.

tavel, J. E. See Hutton, R. S.

Richards, J. W. Present metallurgy of aluminium. Electrochem. Ind., vol. 1, 1902, p. 158.

——— Aluminium nitride. Trans. Am. Electrochem Soc., vol. 23, 1913, p. 351.

Richardson, H. Some observations on laboratory production of aluminium. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 159.

Thompson, M. de Kay. The electrolytic reduction of aluminium as a laboratory experiment. Electrochem. and Met. Ind., vol. 7, 1909, p. 14.

Tucker, S. A. The preparation of aluminium in the laboratory. Electrochem. and Met. Ind., vol. 7, 1909, p. 315.

ARC FURNACE.

Alexander, W. A., Tucker, S. A., and Hudson, H. K. Relative efficiency of the arc and resistance furnace for the manufacture of calcium carbide. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 411.

Hansen, C. A. Small experimental Héroult furnace. Electrochem. and Met. Ind., vol. 7, 1909, p. 206.

Hudson, H. K. See Alexander, W. A.

Thompson, M. de Kay. Preparation and properties of calcium carbide. Trans. Am. Electrochem. Soc., vol. 16, 1909, p. 197.

Tone, F. T. Production of silicon in the electric furnace. Trans. Am. Electrochem. Soc., vol. 7, 1905, p. 243.

Tucker, S. A. The preparation of silicon in the laboratory. Met. and Chem. Eng., vol. 8, 1910, p. 19.

——— See also Alexander, W. A.

Weedon, W. S. A contribution to the study of the electric arc. Trans. Am. Electrochem. Soc., vol. 5, 1904, p. 171.

——— The titanium arc. Trans. Am. Electrochem. Soc., vol. 16, 1909, p. 217.

Whitney, W. R. Arcs. Trans. Am. Electrochem. Soc., vol. 7, 1905, p. 291.

CALCIUM AND MAGNESIUM.

Badger, W. L., and Frary, F. C. The preparation of calcium. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 185.

Bicknell, H. R., Frary, F. C., and Tronson, C. A. Efficiency in the electrolytic production of metallic calcium. Trans. Am. Electrochem. Soc., vol. 18, 1910, p. 117.

Frary, F. C. See Badger, W. L.; also Bicknell, H. R.

Johnson, A. R. The electrolytic preparation of calcium. Trans. Am. Electrochem. Soc., vol. 18, 1910, p. 125.

Jouard, F. L., and Tucker, S. A. The electrolytic preparation of magnesium. Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 249.

Tronson, C. A. See Bicknell, H. R.

Tucker, S. A. See Jouard, F. L.

COPPER.

Haanel, E. Report of the commission appointed to investigate the different electrothermic processes for the smelting of iron ores and the making of steel in operation in Europe. Canada, Department of Interior, Mines Branch, 1904. Report on electric copper smelting by Vatier.

Keeney, R. M., and Lyon, D. A. The smelting of copper ores in the electric furnace. Am. Inst. Min. Eng., No. 80, Aug., 1913, p. 2151; Met. and Chem. Eng., vol. 11, 1913, p. 522.

Lyon, D. A. See Keeney, R. M.

Richards, J. W. Metallurgical calculations. Electric smelting of copper ores. Electrochem. and Met. Ind., vol. 5, 1907, p. 496.

——— The electric furnace in nonferrous metallurgy. Met. and Chem. Eng., vol. 8, 1910, p. 233.

Schilowski, J. La fusion électrique de cuivre et des produits intermediares de fonderies de cuivre. Rev. de Mét., vol. 9, 1912, p. 205.

Stephan, M. Einiges über die Erzeugung von Metallen im elektrischen Ofen. Metall. und Erz., vol. 1, 1912, p. 11.

Weeks, C. A. Melting nonferrous metals in an electric furnace. Met. and Chem. Eng., vol. 9, 1911, p. 363.

Wolkoff, W. Electric smelting of copper sulphide ores. Metallurgie, vol. 7, 1910, p. 99.

ELECTRODES.

Clocher, W. Manufacture of carbons. Met. and Chem. Eng., vol. 9, 1911, p. 137.

Collens, C. L. Graphite electrodes in electrometallurgical processes. Trans. Am. Electrochem. Soc., vol. 1, 1902, p. 53.

Fitzgerald, F. A. J. On testing of carbon electrodes. Trans. Am. Electrochem. Soc., vol. 2, 1902, p. 43.

——— On carbons for electrometallurgy. Trans. Am. Electrochem. Soc., vol. 11, 1907, p. 317.

Fitzgerald, F. A. J., and Hinckley, A. T. Experiments with furnace electrodes. Trans. Am. Electrochem. Soc., vol. 23, 1913, p. 333.

Forsell, J. Current densities and energy losses in electrodes. Met. and Chem. Eng., vol. 8, 1910, p. 26.

Hansen, C. A. Furnace electrode losses. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 279; vol. 16, 1909, p. 329.

——— Furnace electrode losses. Electrochem. and Met. Ind., vol. 7, 1909, pp. 358, 389.

Hering, C. Laws of electrode losses in electric furnaces. Trans. Am. Electrochem. Soc., vol. 16, 1909, p. 265.

——— A new method of measuring mean thermal and electrical conductivities of furnace electrodes. Trans. Am. Electrochem. Soc., vol. 16, 1909, p. 317.

——— Determination of the constants of materials for furnace electrodes. Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 151.

——— Empirical laws of furnace electrodes. Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 171.

——— Method for determining thermal conductivities. Trans. Am. Electrochem. Soc., vol. 18, 1910, p. 213.

——— Furnace electrode losses. Electrochem. and Met. Ind., vol. 7, 1909, p. 400.

——— Properties and behavior of furnace electrodes. Met. and Chem. Eng., vol. 7, 1909, p. 442; Discussion, vol. 9, 1910, pp. 42, 67, 665; vol. 10, 1910, pp. 128, 154, 206.

——— Electrode efficiency of furnaces. Electrochem. and Met. Ind., vol. 7, 1909, p. 473.

——— Chilling and heating of electrodes. Met. and Chem. Eng., vol. 8, 1910, p. 188.

——— Electrode design. Proc. Am. Inst. Elec. Eng., vol. 29, 1910, p. 285.

Hering, C., and Kennelly, A. E. Furnace electrode losses. Met. and Chem. Eng., vol. 8, 1910, p. 238.

Hinckley, A. T. See Fitzgerald, F. A. J.

Kennelly, A. E. The modification in Hering's law of electrodes by including variations in electric and thermal resistivity. Proc. Am. Inst. Elec. Eng., vol., 29, 1910, p. 465.

——— Electrode-holder construction for electric furnaces. Met. and Chem. Eng., vol. 11, 1913, p. 321.

——— Manufacture of carbon electrodes. Met. and Chem. Eng., vol. 9, 1911, pp. 42, 67, 111, 137, 221, 377, 559, 665.

—— Production of electrodes. Met. and Chem. Eng., vol. 8, 1910, p. 291.

— See also Hering, C.

Moissan, H. Electrodes. Compt. Rend., vol. 135, p. 1902.

Roeber, E. F. Electrode losses in electric furnaces. Trans. Am. Electrochem. Soc., vol. 16, 1909, p. 363.

Roush, G. A. Manufacture of carbons for steel furnaces. Jour. Ind. and Eng. Chem., vol. 1, 1909, p. 286.

Turnbull, R. Furnace electrodes practically considered. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 397.

ELECTROMECHANICAL FORCES.

Harden, J. The "pinch" effect in electric furnaces of the induction type. Electrochem. and Met. Ind., vol. 7, 1909, p. 478.

Hering, C. Formulas for the pinch phenomenon. Met. and Chem. Eng., vol. 9, 1911, p. 86.

——— A practical limitation of resistance furnaces; the pinch phenomenon. Trans. Am. Electrochem. Soc., vol. 21, 1907, p. 329.

——— The working limit in electric furnaces due to the "pinch" phenomenon. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 255.

——— A new type of electric furnace. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 255.

——— Electric furnaces for molten materials. Met. and Chem. Eng., vol. 9, 1911, p. 37; Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 255.

——— An imperfection in the usual statement of the fundamental law of electromagnetic induction. Proc. Am. Inst. Elec. Eng., vol. 27, 1908, p. 134.

Northrup, E. F. Some newly observed manifestations of forces in the interior of an electric conductor. Physical Rev., vol. 24, No. 6, 1907, p. 474.

Scott, E. K. The Hering "pinch-effect" furnace. Trans. Faraday Soc., vol. 7, 1912, p. 202.

Unger, M. The action of electromechanical forces in the bath of an induction furnace. Met. and Chem. Eng., vol. 10, 1912, p. 263.

ELECTROLYSIS.

Ashcroft, E. A. Factory scale experiments with fused electrolytes. Electrochem. and Met. Ind., vol. 4, 1906, pp. 143, 178, and 357.

Beekman, J. W. An electrolytic furnace method for producing metals. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 171.

Burgess, C. F. Electrolytic refining as a step in the production of steel. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 181.

Chance, E. M. A new method for the electrolytic winning and refining of metals. Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 235.

Goodwin, H. M., and Mailey, R. D. On the density, electrical conductivity, and viscosity of fused salts. Trans. Am. Electrochem. Soc., vol. 11, 1907, p. 211.

Mailey, R. D. See Goodwin, H. M.

FERRO-ALLOYS.

Ballagh, J. C., and Iwai, K. Investigation of ferroboron. Min. and Sci. Press, vol. 99, 1909, p. 185.

Bennett, S. R., Copeman, S. M., and Hahe, H. W. Manufacture and transport of ferrosilicon. Yellow book of British Local Government Board; Met. and Chem. Eng., vol. 8, 1910, p. 133; Iron and Coal Trades Rev., vol. 80, 1910, p. 45.

Carnot, and Goutal. Recherches sur l'etat oú se trouvent le silicium et le chrome dans les produits sidèrurgiques. Compt. Rend., vol. 126, 1898, p. 1240.

Catani, R. The application of electricity in the metallurgy of Italy. Jour. Iron and Steel Inst., vol. 84, No. 2, 1911, p. 215; Met. and Chem. Eng., vol. 9, 1911, p. 642.

Chaplet, M. Les alliages ferrométalliques, Rev. de Met., vol. 6, 1909, p. 739.

Conrad, W. Electric furnaces for the manufacture of calcium carbide and ferrosilicon. Electrochem. and Met. Ind., vol. 6, 1908, p. 397.

Conrad, W., and **Pick**, W. Die Herstellung von Hochprozentigem Ferrosilizium im elektrischen Ofen. Pub. by W. Knappe, Halle, Germany, 1909; Rev. de Met., vol. 9, 1912, p. 362.

Copeman, S. M. See Bennett, S. R.

Electrochemical Industry. Ferrosilicon made in the electric furnace. Vol. 2, 1904, p. 122.

Electrochemical and Metallurgical Industry. Ferro-alloys. Vol. 4, 1906, p. 247.

Engineer (London). The manufacture and use of ferro-alloys. Vol. 105, 1908, pp. 80 and 105.

Escard, M. Ferrosilicium. La Lumière Electrique. Mar. 6, 1909.

Genie Civil. La fabrication du ferromanganese en France. Feb. 10, 1906.

Gin, G. Decarburization of ferro-alloys. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 225.

——— Ferrosilicium. L'Eclairage Electrique, vol. 27, May 4, 1900.

——— Memoirs on the methods of treatment of simple and complex ores of molybdenum, tungsten, uranium, and vanadium. Trans. Am. Electrochem. Soc., vol. 12, 1907, p. 411; vol. 13, 1908, p. 481; vol. 16, 1909, p. 393.

——— Note upon the manufacture of silicovanadium. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 229.

——— Preparation of ferrovanadium by electrolysis. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 227.

Girod, P. Les alliages ferrométalliques. Société des Ingeneurs Civils de France, Nov., 1906.

Goutal, see Carnot.

Greenwood, H. C., **Slade**, R. E., and **Pring**, J. N. Reduction of refractory oxides, production of ferro-alloys, and formation of carbides. Trans. Chem. Soc., vol. 93, 1908, p. 1484, Electrochem. and Met. Ind., vol. 7, 1909, p. 119.

Guichard, M. Production of molybdenum from molybdenite. Compt. Rend., vol. 122, p. 1270.

Hadfield, R. A. Alloys of iron and tungsten. Jour. Iron and Steel Inst., vol. 64, No. 2, 1903, p. 14.

Hahe, H. W., see Bennett, S. R.

Haughton, E. Ferro-alloys in the foundry. Electrochem. and Met. Ind., vol. 5, 1907, p. 9.

Hutton, R. S. Recent advances in the electrometallurgy of iron and steel. Soc. Chem. Ind., vol. 24, pt. 1, 1905, p. 590.

Iron Trade Review. Ferrovanadium. Vol. 51, 1912, p. 275.

Iwai, K. See Ballagh, J. C.

Jakoki, J. Ferromanganese in Hochofen. Stahl und Eisen., vol. 29, 1909, p. 1191.

Keeney, R. M. The production of steels and ferro-alloys directly from ore in the electric furnace. Jour. Iron and Steel Inst., vol. 4, 1912, p. 108.

——— Electric smelting of chromium, tungsten, molybdenum, and vanadium ores. Trans. Am. Electrochem Soc., vol. 24, 1913, p. 167; Met. and Chem. Eng., vol. 11, 1913, p. 585.

Keeney, R. M., and **Lee**, G. M. The direct production of steels and ferro-alloys from ore in the electric furnace. West. Chem. and Metal, vol. 6, 1910, pp. 269, 323, 347.

Keeney, R. M., and **Lyon**, D. A. Possible application of the electric furnace to western metallurgy. Trans. Am. Electrochem. Soc., vol. 24, 1913, p. 119; Met. and Chem. Eng., vol. 11, 1913, p. 577.

Keller, C. A. The electric furnace and the manufacture of ferro-alloys. Jour. Iron and Steel Inst., vol. 63, 1903, No. 1, p. 162.

Lebeau, P. Sur les gas toxiques dégagee par les ferrosilicium sous l'action l'air humide. Rev. de Métal., vol. 6, 1909, p. 907.

Lee, G. M. See Keeney, R. M.

Lehner, W. Herstellung von Molybdenum. Metallurgie, vol. 3, 1906, p. 549.

Louis, J. La fabrication des ferrosilicium au four electrique. Jour. du Four Electrique et de Lumière, Oct. 1, 1910, p. 415.

Lyon, D. A. See Keeney, R. M.

Metallurgical and Chemical Engineering. Electric smelting of nickel ore. Vol. 8, 1910, p. 277.

——— Swedish methods of packing ferrosilicon. Vol. 11, 1913, p. 87.

Moissan, H. Compt. Rend., vol. 121, p. 621.

Morrison, W. L. Electric-furnace treatment of nickel ore and the development of a commercial process. Trans. Am. Electrochem. Soc., vol. 20, 1911, p. 315; Met. and Chem. Eng., vol. 9, 1911, p. 546.

Neumann, B. Herstellung von Ferro-liegierung im elektrischen Ofen. Stahl und Eisen, vol. 28, 1908, p. 356.

Pick, W. See Conrad, W.

Petavel. Ferrosilicium. Journal d'Electrolyse, vol. 3, June 3, 1904.

Pratt, L. R. Manufacture of metallic tungsten and ferrotungsten in the crucible. Electrochem. and Met. Jour., vol. 90, 1910, p. 959.

Pring, J. N. See Greenwood, H. C.

Rossi, A. J. Ferro-alloys. Min. Ind., vol. 12, 1903, p. 693.

——— Exhibit of ferrometals made electrically, and of other electric-furnace products. Trans. Am. Electrochem. Soc., vol. 5, 1904, p. 275.

——— On the manufacture of ferro-alloys in general and of ferrotitanium in particular in the electric furnace. Electrochem. Ind., vol. 1, 1903, p. 523.

Scholl, G. P. Manufacture of ferro-alloys in the electric furnace. Electrochem. Ind., vol. 2, 1904, pp. 349, 395, 449.

Scroeder, F. Remelting of ferromanganese in the electric furnace and the use of molten ferromanganese for deoxidization. Met. and Chem. Eng., vol. 9, 1910, p. 640.

Sjöstedt, E. A. Electric-smelting experiments for the manufacture of ferronickel from pyrrhotite. Trans. Am. Electrochem. Soc., vol. 5, 1904, p. 233.

Slade, R. E. See Greenwood, H. C.

Slocum, C. V. Titanium in iron and steel. Trans. Am. Electrochem. Soc., vol. 20, 1911, p. 265.

Stansfield, A. The electrothermic production of steel from iron ore. Trans. Can. Min. Inst., vol. 10, 1907, p. 128.

——— Tool steel direct from ore in an electric furnace. Trans. Can. Min. Inst., vol. 13, 1910, p. 151.

Stassano, E. Treatment of iron and steel in the electric furnace. Electrochem. and Met. Ind., vol. 6, 1908, p. 35.

Steinhart, D. J. Notes on metals and their ferro-alloys used in the manufacture of alloy steels. Inst. Min. and Met., vol. 15, 1905; p. 228; Min. Jour., 1906, p. 128.

Stephan, M. Einiges über die Erzeugung von Metallen im elektrischen Ofen. Metall. und Erz, vol. 1, 1912, p. 11.

Taussig, R. Large electric furnace. Trans. Faraday Soc., vol. 5, 1909, p. 254.

——— Present status of the development of large electric furnaces. Met. and Chem. Eng., vol. 10, 1912, p. 686.

Venator, W. Ueber Eisen Legierungen und Metall für die Stahl Industrie. Stahl und Eisen, vol. 28, 1908, p. 41; Iron and Coal Trades Rev., vol. 76, 1908, p. 520

Weintraub, E. Preparation and properties of pure boron. Trans. Am. Electrochem. Soc., vol. 16, 1909, p. 165.

FURNACES.

Adler, E., and Sabersky, E. A new electrical hardening furnace. Trans. Faraday Soc., vol. 5, 1909, p. 15.

Fitzgerald, F. A. J. Experiments with an electrothermic muffle furnace. Electrochem. and Met. Ind., vol. 3, 1905, p. 135.

——— The Borchers furnace. Electrochem. and Met. Ind., vol., 3, 1905, p. 215.

——— The Ruthenburg and Acheson furnaces. Electrochem. and Met. Ind., vol. 3, 1905, p. 416.

Harden, J. Some electric-furnace notes. Met. and Chem. Eng., vol. 9, 1911, p. 130.

Johnson, W. McA. Rotary electric furnace. Electrochem. and Met. Ind., vol. 4, 1906, p. 321.

Sabersky, E. See Adler, E.

Taylor, E. R. The manufacture of bisulphide of carbon in the electric furnace. Trans. Am. Electrochem. Soc., vol. 1, 1902, p. 115.

——— Some advances in the closed and continuous working electric furnace. Trans. Am. Electrochem. Soc., vol. 2, 1902, p. 185.

——— A closed electric furnace for reducing and distilling metals from their ores. Trans. Am. Electrochem. Soc., vol. 11, 1907, p. 294.

GENERAL DESCRIPTION.

Bennie, P. McN. The electric furnace, its place in siderology. Trans. Can. Min. Inst., vol. 13, 1910, p. 135.

Brown, O. W. The reduction of metal sulphides. Trans. Am. Electrochem. Soc., vol. 9, 1906, p. 109.

Burgess, C. F. The present status of electric-furnace working. Jour. West. Soc. Eng., vol. 10, 1905, p. 16.

Catani, R. The application of electricity in the metallurgy of Italy. Jour. Iron and Steel Inst., vol. 84, No. 2, 1911, p. 215; Met. and Chem. Eng., vol. 9, 1911, p. 642.

Dushman, S. Electrochemical and electrometallurgical developments in Canada. Trans. Am. Electrochem. Soc., vol. 20, 1911, p. 419.

Farnsworth, L. D. Experimental electric smelting. Electrochem. and Met. Ind., vol. 6, 1908, p. 326.

Harden, J. Some electric-furnace notes. Met. and Chem. Eng., vol. 9, 1911, p. 130.

Hering, C. Advantage of small high-speed electric furnaces. Met. and Chem. Eng., vol. 11, 1913, p. 183.

——— Elementary principles of the design and operation of electric furnaces. Met. and Chem. Eng., vol. 8, 1910, p. 471.

Hutton, R. S. On the fusion of quartz in the electric furnace. Trans. Am. Electrochem. Soc., vol. 2, 1909, p. 105.

Johnson, W. McA., and Sieger, G. N. Electric furnaces, their design, characteristics, and commercial application. Met. and Chem. Eng., vol. 11, 1913, pp. 504, 563, 643.

Keeney, R. M., and Lyon, D. A. Possible applications of the electric furnace to Western metallurgy. Trans. Am. Electrochem. Soc., vol. 24, 1913, p. 118. Met. and Chem. Eng., vol. 11, 1913, p. 577.

Kowalke, O. L. Electric-furnace conversion of iron pyrites into a magnetic form. Trans. Am. Electrochem., Soc., vol. 13, 1908. p. 133.

Kunye, W., Beitrag zum Entwicklungstand neulicher elektroöfen. Stahl und Eisen, vol. 32, 1912, p. 1181.

Louvrier, F. Electric heat vs. heat from fuel. Electrochem. and Met. Ind., vol. 5, 1907, p. 298.

——— Electric and fuel furnaces compared. Electrochem. and Met. Ind., vol. 7, 1909, p. 159.

Lyon, D. A. See Keeney, R. M.

Metallurgical and Chemical Engineering. Editorial on the electric furnace and the scrap-metal business. Vol. 9, 1911, p. 620.

Minet, A. The electric furnace; its origin, transformation, and applications. Trans. Faraday Soc., vol. 1, 1905, p. 77; vol. 2, 1906, p. 1.

Nernst, W. Determination of vapor densities in an electric furnace. Trans. Am. Electrochem. Soc., vol. 3, 1903, p. 75.

Richards, J. W. Conditions of progress in electrochemistry. Trans. Am. Electrochem. Soc., vol. 3, 1903, p. 59.

——— Electrochemistry at Sault Ste. Marie. Electrochem. Ind., vol. 1, 1902, p. 85.

——— Furnace efficiency. Electrochem. Ind., vol. 1, 1902, p. 46.

——— Niagara as an electrochemical center. Electrochem. Ind., vol. 1, 1902, p. 11.

——— The efficiency of electric furnaces. Trans. Am. Electrochem. Soc., vol. 2, 1902, p. 51.

——— The electrochemical industries of Norway. Trans. Am. Electrochem. Soc., vol. 20, 1911, p. 403.

——— The electric furnace in nonferrous metallurgy. Met. and Chem. Eng., vol. 8, 1910, p. 233.

——— What electrochemistry is accomplishing. Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 75.

Richards, J. W., and Hering, C. Efficiency—A discussion. Met. and Chem. Eng., vol. 9, 1911, p. 125.

Ruthenburg, M. Electric smelting furnaces and their applications. Trans. Am. Electrochem. Soc., vol. 18, 1910, p. 185.

Sieger, G. N. See Johnson, W. McA.

Snyder, F. T. The reliability of electric furnaces for commercial work. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 185.

Wellman, S. F. Discussion of the electric furnace. Iron Trade Rev., vol. 50, 1912, p. 1224.

GOLD AND SILVER.

Conklin, H. R. Electric furnace at Lluvia de Oro. Eng. and Min. Jour., vol. 93, 1912, p. 1189.

HEAT LOSSES.

Clement, J. K., and Egy, W. L. Measurement of thermal conductivity of fire clay Bull. 36, Eng. Exper. Sta., University of Illinois.

Egy, W. L. See also Clement, J. K.

Electrochemical and Metallurgical Industry. Heating furnace walls to reduce heat losses. Vol. 7, 1909, p. 494.

Fitzgerald, F. A. J. Experiments on heat insulation. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 535.

——— Heat losses in furnaces. Trans. Am. Electrochem. Soc., vol. 22, 1912, p. 111.

——— Heat losses of the electric furnace. Met. and Chem. Eng., vol. 9, 1911, p. 1270.

——— On the heat conductivity of carbon. Trans. Am. Electrochem. Soc., vol. 12, 1907, p. 165.

——— The use of carbon for the study of temperatures in the electric furnace. Trans. Am. Electrochem. Soc., vol. 6, 1904, p. 32.

Hering, C. Effects of the variations of thermal resistivities with the temperature. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 511.

——— Heat conductance and resistance of composite bodies. Electrochem. and Met. Ind., vol. 7, 1909, p. 11.

——— Heat conductance through walls of furnaces. Trans. Am. Electrochem. Soc., vol. 14, 1908, p. 215.

Herring, C. Improving the output and efficiency of existing electric furnaces. Met. and Chem. Eng., vol. 8, 1910, p. 276.

——— Method for determining thermal conductivities. Trans. Am. Electrochem. Soc., vol. 18, 1910, p. 213.

——— The thermal insulation of furnace walls. Met. and Chem. Eng., vol. 10, 1912, p. 97.

Kreisinger, Henry. See Ray, W. T.

Metallurgical and Chemical Engineering. Electric-furnace temperature regulation. Vol. 8, 1910, p. 96.

Ray, W. T., and Kreisinger, Henry. The flow of heat through furnace walls. Bull. 8, Bureau of Mines, 1911, 32 pp.

Randolph, C. P. The thermal resistivity of insulating materials. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 545.

Saunders, L. E. Temperature measurements on the silicon carbide furnace. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 425.

Snyder, F. T. The flow of heat through furnace walls. Trans. Am. Electrochem. Soc., vol. 18, 1910, p. 235.

INDUCTION FURNACE.

Englehardt, V. Electric induction furnace for making steel. Electrochem. and Met. Ind., vol. 3, 1905, p. 294.

——— The induction furnace and its use in the steel industry. Electrochem. and Met. Ind., vol. 6, 1908, p. 143.

Fitzgerald, F. A. J. Experiments on melting in the induction furnace. Electrochem. and Met. Ind., vol. 7, 1909, p. 10.

Gin, G. Mathematics of the induction furnace. Trans. Am. Electrochem. Soc., vol. 12, 1907, p. 97.

Harden, J. Induction-furnace notes. Met. and Chem. Eng., vol. 11, 1913, p. 559.

——— Present status of the induction furnace. Met. and Chem. Eng., vol. 11, 1913, p. 99.

——— The efficiency of induction furnaces. Electrochem. and Met. Ind., vol. 7, 1909, p. 320.

Hiarth, A. Design of a 30-ton induction electric furnace. Trans. Am. Electrochem. Soc., vol. 20, 1911, p. 293.

Neumann, B., Röchling, W., and Rodenhauser, W. Induction furnace for three-phase currents. Electrochem. and Met. Ind., vol. 6, 1908, p. 458.

LABORATORY FURNACES.

Bard, E. F., and Calhane, D. F. An efficient electric furnace for high temperatures. Met. and Chem. Eng., vol. 10, 1912, p. 416.

Calhane, D. F., see Bard, E. F.

Electrochemical and Metallurgical Industry. Electric laboratory furnaces. Vol. 7, 1908, pp. 219, 222.

——— Laboratory furnaces. Vol. 6, 1909, p. 256.

——— Rheostat for small electric furnaces. Vol. 7, 1909, p. 168.

Fitzgerald, F. A. J. Electric laboratory furnace. Electrochem. and Met. Ind., vol. 3, 1906, p. 55.

——— Experiments with an electrothermic muffle furnace. Electrochem. and Met. Ind., vol. 3, 1905, p. 135.

Hutton, R. S., and Patterson, W. H. Electrically heated carbon tube furnaces. Trans. Faraday Soc., vol. 1, 1905, p. 187.

Patterson, W. H. See Hutton, R. S.

White, G. R. Laboratory resistance furnace. Trans. Am. Electrochem. Soc., vol. 9, 1906, p. 143.

PIG IRON.

BENNIE, P. McN. Electric-furnace pig iron in California. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 35.

——— Application of the electric furnace to the metallurgy of iron and steel. Electrochem. Ind., vol. 2, 1904, p. 307.

CAMPBELL, D. E. Progress in the electrometallurgy of iron and steel. Trans. Faraday Soc., vol. 7, 1912, p. 195.

CARCANO, F. E. The production of pig iron in the electric furnace and the industrial utilizations of pyrite residue. Electrochem. and Met. Ind., vol. 7, 1909, p. 155.

CATANI, R. Large electric furnaces in the electrometallurgy of iron and steel. Trans. Am. Electrochem. Soc., vol. 15, 1909; p. 159; Electrochem. and Met. Ind., vol. 7, 1909, p. 268.

——— Reduction of iron ore in the electric furnace. Electrochem. and Met. Ind., vol. 7, 1909, p. 153.

CRAWFORD, J. Progress of electric smelting at Heroult, California. Met. and Chem. Eng., vol. 11, 1913, p. 386.

ELECTROCHEMICAL AND METALLURGICAL INDUSTRY. Iron reduction at the "Soo" by the Héroult electric furnace process. Vol. 4, 1906, p. 124.

——— Electric iron and steel industry in Canada and in Sweden and Norway. Vol. 7, 1909, p. 419.

FRICK, O. Electric reduction of iron ores with special reference to results obtained in electro-metals furnace at Trollhättan, Sweden, and Noble furnace at Heroult, California. Met. and Chem. Eng., vol. 9, 1911, p. 631.

GIN, G. On the electrical reduction of titaniferous iron ores. Trans. Am. Electrochem. Soc., vol. 11, 1907, p. 291.

GREENE, A. E., and MACGREGAR, F. S. On the electrothermic reduction of iron ores. Trans. Am. Electrochem. Soc., vol. 12, 1907, p. 65.

HAANEL, E. Investigation of an electric shaft furnace, Domnarfvet, Sweden. Trans. Faraday Soc., vol. 5, 1909, p. 306.

——— Preliminary report on the experiments made at Sault Ste. Marie under Government auspices on the smelting of Canadian iron ores by the electrothermic process. Trans. Faraday Soc., vol. 2, 1906, p. 120.

——— The electric shaft furnace of the Aktiebolaget Elektrometall, Ludvika, Sweden. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 25.

HARBORD, F. W. Recent developments in electric smelting in connection with iron and steel. Trans. Faraday Soc., vol. 1, 1905, p. 140.

HARDEN, J. Smelting iron ores in the electric furnace in comparison with blast-furnace practice. Electrochem. and Met. Ind., vol. 7, 1909, p. 16.

KEENEY, R. M., and LYON, D. A. Possible applications of the electric furnace to western metallurgy. Trans. Am. Electrochem. Soc., vol. 24, 1913, p. 118; Met. and Chem. Eng., vol. 11, 1913, p. 577.

KELLER, C. A. Contribution to the study of electric furnaces as applied to the manufacture of iron and steel. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 87.

——— Electrothermics of iron and steel. Trans. Faraday Soc., vol. 2, 1906, p. 36.

LEFFLER, J. A., and NYSTRÖM, E. Electric furnace pig iron at Trollhättan. Met. and Chem. Eng., vol. 10, 1912, p. 413.

LEFFLER, J. A., and ODELBERG, E. The electric iron reduction plant at Trollhättan, Sweden. Met. and Chem. Eng., vol. 9, 1911, pp. 368, 459, and 505.

LYON, D. A. The electric furnace in the production of pig iron from ore. Met. and Chem. Eng., vol. 11, 1913, p. 15.

——— The Noble Electric Steel Company's plant. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 39.

——— The use of electric-furnace pig iron in the open-hearth furnace. Met. and Chem. Eng., vol. 10, 1912, p. 539.

——— See also Keeney, R. M.

LYMAN, J. The electric furnace for the manufacture of iron and steel. Trans. Am. Electrochem. Soc., vol. 19, 1910, p. 193.

MACGREGAR, F. S. See Greene, A. E.

NEUMANN, B. Electric-furnace methods in iron and steel manufacture in comparison with ordinary metallurgical processes. Electrochem. Ind., vol. 2, 1904, p. 488,

NYSTRÖM, E. See Leffler, J. A.

ODELBERG, E. See Leffler, J. A.

RICHARDS, J. W. Discussion of the experiments made at Sault Ste. Marie on the electrical reduction of iron ores. Trans. Am. Electrochem. Soc., vol. 12, 1907, p. 81.

——— Electric reduction of iron ore. Jour. Franklin Inst., vol. 169, 1910, p. 131.

——— Gas circulation in electric reduction furnaces. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 403.

——— Metallurgical calculations; the electrometallurgy of iron and steel. Electrochem. and Met. Ind., vol. 5, 1907, p. 165.

——— The electrometallurgical revolution in iron and steel industry of Norway and Sweden. Proc. Eng. Soc. West. Pa., vol. 27, 1911, p. 125.

——— The electrothermic production of iron and steel, method and furnace. Jour. Franklin Inst., vol. 164, 1907, p. 443; vol. 165, 1908, p. 47.

——— The electric-furnace reduction of iron ore. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 53.

ROBERTSON, T. D. Recent progress in electrical iron smelting in Sweden. Trans. Am. Electrochem., Soc., vol. 20, p. 375.

ROSSI, A. J. Electric-smelting and blast-furnace gases. Electrochem. and Met. Ind., vol. 3, 1904, pp. 150, 190.

——— Note on the utilization of blast-furnace gases in connection with the electric smelting of iron. Trans. Am. Electrochem. Soc., vol. 7, 1905, p. 199.

SIMPSON, L. The electric reduction of iron ores and the conversion of iron into steel in an electric furnace. Electrochem. Ind., vol. 1, 1903, p. 277.

STANSFIELD, A. Laboratory experiments on removing silicon and phosphorus in smelting iron ores. Trans. Can. Min. Inst., vol. 10, 1907, p. 128.

TAYLOR, E. R. Contribution to the electric smelting of iron ore. Trans. Am. Electrochem. Soc., vol. 16, 1909, p. 229.

YNGSTROM, L. Electric blast furnace at Domnarfvet, Sweden. Met. and Chem. Eng., vol. 8, 1910, p. 11.

——— Electric production of iron from iron ore at Domnarfvet. Engineering (London), vol. 109, 1910, pp. 206, 234.

POWER.

ASHCROFT, E. A. The influence of cheap electricity on electrolytic and electrothermal industries. Trans. Faraday Soc., vol. 4, 1908, pp. 134, 149.

CRABTREE, F. Possibilities of cheap power in the Pittsburgh district. Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 95.

ELECTROCHEMICAL AND METALLURGICAL INDUSTRY. Regulation of current in electric furnaces. Vol. 3, 1905, p. 9.

JONES, A. J. Transforming stations of Niagara electrochemical and electrometallurgical industries. Trans. Am. Electrochem. Soc., vol. 20, 1911, p. 455.

KNESCHE, F. A. Electric smelting of ore in the United States (an investigation of the possibility of utilizing energy from waste fuels). Iron Trade Rev., vol. 48, 1911, p. 65.

LUCKE, C. E. Power cost. Trans. Am. Electrochem. Soc., vol. 11, 1907, p. 339.

MEYER, J. Electrochemical processes as station-load equalizers. Trans. Am. Electrochem. Soc., vol. 11, 1907, p. 369.

——— Power for electrochemical purposes. Trans. Am. Electrochem. Soc., vol. 14, 1908, p. 377.

Metallurgical and Chemical Engineering. The power problem for electrochemical plants. Vol. 9, 1911, p. 384.

Northrup, E. F. A new type of ammeter for the accurate measurement of alternating currents above 1,000 amperes. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 303.

Randall, K. C. A study in heavy alternating-current conductors for electric furnaces. Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 139.

Scott-Hansen, A. Hydroelectric plants in Norway and their application to electrochemical industries. Trans. Faraday Soc., vol. 7, 1911, p. 78.

Simpson, L. Cost of electric power used in electric reduction works. Electrochem. Ind., vol. 2, p. 421.

Sperry, E. A. Electrochemical processes as station-load equalizers. Trans. Am. Electrochem. Soc., vol. 9, 1906, p. 147.

——— Utilization of power stations for electrochemical and electrothermal processes during periods of low load. Trans. Am. Electrochem. Soc., vol. 14, 1908, p. 259.

Sykes, W. Power supply to electric furnaces for refining iron and steel. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 383.

Wilson, J. R. High-tension equipment for electrochemical plants. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 371.

REFRACTORY MATERIALS.

Bleininger, A. V., and Brown, G. H. Testing of clay refractories, with special reference to their load-carrying capacities. Bureau of Standards Technologic Paper 7, 1911, 78 pp.

Brown, G. H. See Bleininger, A. V.

Journal of Industrial and Engineering Chemistry. Committee on specifications for refractories of Institute of Gas Engineers. Vol. 4, 1912, p. 618.

Fitzgerald, F. A. J. Refractory materials in electrical resistance furnaces. Electrochem. Ind., vol. 2, 1904, p. 439.

Harbison-Walker Refractories Co. Refractories in furnace construction. Met. and Chem. Eng., vol. 8, 1910, p. 106.

Kanolt, C. W. Melting points of fire bricks. U. S. Bureau of Standards Technologic Paper 10, 1912, 17 pp.

McLeod, D. L., Stansfield, A., and McMahon, J. W. The electrical resistivity of fire bricks at high temperatures. Trans. Am. Electrochem. Soc., vol. 22, 1912, p. 89.

McMahon, J. W. See McLeod, D. L.

Queneau, A. L., and Wolgodine, S. Conductivity, porosity, and gas permeability of refractory materials. Electrochem. and Met. Ind., vol. 7, 1909, p. 383.

Rigg, G. Defects in refractory brick and their causes. Met. and Chem. Eng., vol. 8, 1910, p. 237.

Stansfield, A. See McLeod, D. L.

Wolgodine, S. See Queneau, A. L.

RESISTANCE FURNACE.

Alexander, W. A., Tucker, S. A., and Hudson, H. K. Relative efficiency of the arc and resistance furnace for the manufacture of calcium carbide. Trans: Am. Electrochem. Soc., vol. 15, 1909, p. 411.

Cauchois, R. W., Doty, A., and Tucker, S. A. Granular-carbon resistors. Trans. Am. Electrochem. Soc., vol. 12, 1907, p. 171.

Collens, C. L. Some principles of resistor-furnace design. Trans. Am. Electrochem. Soc., vol. 9, 1906, p. 31.

Dempster, J. T. K. Alloys for resistors. Electrochem. and Met. Ind., vol. 8, 1910 p. 14.

Electrochemical and Metallurgical Industry. The works of the International Acheson Graphite Co. at Niagara Falls. Vol. 7, 1909, p. 187.

Doty, A. See also Cauchois, R. W.

Fitzgerald, F. A. J. A new electric resistance furnace. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 273; Met. and Chem. Eng., vol. 9, 1911, p. 259.

——— A new resistor furnace. Met. and Chem. Eng., vol. 8, 1910, p. 317.

——— Industrial resistance furnaces. Electrochem. and Met. Ind., vol. 3, 1905, p. 297.

——— Materials for resistors. Electrochem. Ind., vol. 2, 1904, p. 490.

——— Miscellaneous accessories of resistor furnaces. Electrochem. and Met. Ind., vol. 3, 1905, p. 9.

——— Note on an unsuccessful furnace experiment. Trans. Am. Electrochem. Soc., vol. 20, 1911, p. 281.

——— Note on some theoretical considerations in the construction of resistance furnaces. Trans. Am. Electrochem. Soc., vol. 4, 1903, p. 9.

——— Refractory materials in electrical resistance furnaces. Electrochem. Ind., vol. 2, 1904, p. 439.

——— Resistance furnace for crucibles. Electrochem. and Met. Ind., vol. 3, 1905, p. 55.

——— Some first principles of electrical resistance furnaces. Electrochem. Ind., vol. 2, 1904, p. 342.

——— The carborundum furnace. Electrochem. and Met. Ind., vol. 4, 1906, p. 53.

Goodwin, J. H. Granular-carbon resistance furnaces. Met. and Chem. Eng., vol. 9, 1911, p. 188.

Hering, C. A new type of electric furnace. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 255.

——— Electric furnaces for molten materials. Met. and Chem. Eng., vol. 9, 1911, p. 371.

Heumann, E. M., Kudlich, H. F., and Tucker, S. A. The preparation of silundum. Trans. Am. Electrothem Soc., vol. 16, 1909, p. 207.

Hudson, H. K. See Alexander, W. A.

Kudlich, H. F. See Heumann, E. M.

Tucker, S. A. See also Alexander, W. A.; Cauchois, R. W.; and Heumann, E. M.

Watts, O. P. An electric furnace for heating crucibles. Electrochem. and Met. Ind., vol. 4, 1906, p. 273.

STEEL.

Amberg, R. Deoxidation and desulphurization in electric steel furnaces. Electrochem. and Met. Ind., vol. 7, 1909, p. 115.

——— The function of slag in electric steel refining. Trans. Am. Electrochem. Soc., vol. 22, 1912, p. 133; Met. and Chem. Eng., vol. 10, 1912, p. 601.

Arnou, M. G. Notes on the direct reduction of iron ores in the electric furnace. Rev. de Métal., vol. 7, 1910, p. 1190.

Baily, T. F. An electric furnace for heating bars and billets. Trans. Am. Electrochem Soc., vol. 19, 1911, p. 285.

——— Further development of electric furnace for heating bars and billets. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 419.

Bennie, P. McN. Application of the electric furnace to the metallurgy of iron and steel. Electrochem. Ind., vol. 2, 1904, p. 307.

Borchers, W. Electric smelting with the Girod furnace. Trans. Am. Inst. Min. Eng., vol. 41, 1910, p. 120.

Bowman, R. G., and Dittus, E. J. The direct production of molybdenum steel in the electric furnace. Trans. Am. Electrochem. Soc., vol. 20, 1911, p. 355.

Burgess, C. F. Electrolytic refining as a step in the production of steel. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 181.

CAMPBELL, D. F. Electric steel refining. Jour. Iron and Steel Inst., vol. 82, No. 2, 1910, p. 197.

——— Progress in the electrometallurgy of iron and steel. Trans. Faraday Soc., vol. 7, 1912, p. 195.

CATANI, R. Large electric furnaces in the electrometallurgy of iron and steel. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 159; Electrochem. and Met. Ind., vol. 7, 1909, p. 268.

——— The application of electricity in the metallurgy of Italy. Jour. Iron and Steel Inst., vol. 84, No. 2, 1911, p. 215; Met. and Chem. Eng., vol. 9, 1911, p. 642.

CLARK, C. B. Various types and applications of electric steel furnaces. Met. and Chem. Eng., vol. 10, 1912, p. 373.

DITTUS, E. J. See Bowman, R. G.

Electrochemical and Metallurgical Industry. A Swiss electric-furnace steel plant. Vol. 6, 1908, p. 452.

——— Electric iron and steel industry in Canada and in Sweden and Norway. Vol. 7, 1909, p. 419.

——— Removal of sulphur in electric steel furnaces. Vol. 6, 1908, p. 405.

——— The electric furnace in iron and steel metallurgy. Vol. 5, 1907, p. 24.

——— The Girod electric steel furnace. Vol. 6, 1908, p. 428.

Electrochemical Industry. Steel production in the electric furnace. Vol. 1, 1902, p. 247.

ENGLEHARDT, V. Electric induction furnace for making steel. Electrochem. and Met. Ind., vol. 3, 1905, p. 294.

——— The induction furnace and its use in the steel industry. Electrochem. and Met. Ind., vol. 6, 1908, p. 143.

EVANS, J. W. Laboratory experiments on the electric smelting of iron ore. T. Can. Min. Inst., vol. 9, 1906, p. 128.

FITZGERALD, F. A. J. The application of the Lash process to the electric furnace. Ann. Am. Electrochem. Soc, vol. 15, 1909, p. 149.

——— The Lash steel process and the electric furnace. Ann. Am. Electrochem. Soc., vol. 14, 1908, p. 239.

GIN, G. Automatically circulating furnaces of the Gin type for the electrical production of steel. Trans. Faraday Soc., vol. 5, 1909, p. 137.

——— Calculations of a Gin self-circulating induction steel furnace. Ann. Am. Electrochem. Soc., vol. 15, 1909, p. 215.

——— Note on recent developments in the Gin electric steel furnace. Trans. Faraday Soc., vol. 2, 1906, p. 44.

——— The new Gin process for the electrical manufacture of steel. Trans. Am. Electrochem. Soc., vol. 8, 1905, p. 105.

——— The self-circulating Gin furnace for the electric manufacture of steel. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 205.

GIROD, P. Studies in the electrometallurgy of ferro-alloys and steels. Trans. Faraday Soc., vol. 6, 1910, pp. 172–184.

——— The electric steel furnace in foundry practice. Met. and Chem. Eng., vol. 10, 1912, p. 663.

——— The Girod electric furnace for the manufacture of steel. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 127; Electrochem. and Met. Ind., vol. 7, 1909, p. 259.

GREENE, A. E. Electric heating and the removal of phosphorus from iron. Trans. Am. Electrochem. Soc., vol. 22, 1912, p. 123.

——— Electric steel processes as competitors of the Bessemer and open hearth. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 233.

HARBORD, F. W. Recent developments in electric smelting in connection with iron and steel. Trans. Faraday Soc., vol. 1, 1905, p. 140.

Harden, J. A new electric furnace for steel melting and refining. Met. and Chem. Eng., vol. 9, 1911, p. 38.

——— Present status of the induction furnace, Met. and Chem. Eng., vol. 9, 1913, p. 99.

——— Recent developments of the Kjellin and Röchling-Rodenhauser electric induction furnaces. Trans. Faraday Soc., vol. 4, 1908, p. 120.

——— The "Paragon" electric furnace and recent developments in metallurgy. Met. and Chem. Eng., vol. 9, 1911, p. 595; Trans. Faraday Soc., vol. 7, 1912, p. 183.

Hering, C. Possible reduction of the power consumption in electric steel-refining furnaces. Met. and Chem. Eng., vol. 9, 1911, p. 590.

Héroult, P. L. T. Electric steel process. Electrochem. Ind., vol. 1, 1903, p. 449.

——— Electric steel refining. Met. and Chem. Eng., vol. 10, 1912, p. 601.

——— The electrometallurgy of iron and steel. Trans. Am. Electrochem. Soc., vol. 6, 1904, p. 129.

——— The Héroult furnace. Electrochem. and Met. Ind., vol. 5, 1907, p. 411.

Hibbard, H. D. The present value of electrical structural steel. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 231.

Izart, J. The Stassano furnace installed at the new works in Turin. Electrician, Oct. 12, 1907.

Kearns, J. E. Electric annealing furnaces. Electrochem. and Met. Ind., vol. 4, 1906, p. 95.

Keeney, R. M. The production of steels and ferro-alloys directly from ore in the electric furnace. Jour. Iron and Steel Inst., Carnegie Scholarship Memoirs, vol. 4, 1912, p. 108.

Keeney, R. M., and Lee, G. M. The direct production of steels and ferro-alloys from ore in the electric furnace. West. Chem. and Metal., vol. 6, 1910, pp. 269, 323, 347.

Keller, C. A. A contribution to the study of electric furnaces as applied to the manufacture of iron and steel. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 87; Trans. Faraday Soc., vol. 5, 1909, p. 113.

——— Electrothermics of iron and steel. Trans. Faraday Soc., vol. 2, 1906, p. 36.

Kershaw, J. B. C. Electric-furnace manufacture of steel. Iron Trade Rev., vol. 51, 1912, pp. 865, 959, 1007, 1067, 1105, 1169.

Kjellin, F. A. The Kjellin and Röchling-Rodenhauser electric furnace. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 173.

Lee, G. M. See Keeney, R. M.

Lipin, W. The Nathusius electric steel furnace. Met. and Chem. Eng., vol. 10, 1912, p. 227.

Lyman, J. The electric furnace for the manufacture of iron and steel. Trans. Am. Electrochem. Soc., vol. 19, 1910, p. 193.

Metallurgical and Chemical Engineering. South Chicago electric-furnace plant of the United States Steel Corporation. Vol. 8, 1910, p. 179.

——— The electric furnace for small steel castings. Vol. 10, 1912, p. 54.

Moldenke, R. Electric melting for the foundry. Electrochem. and Met. Ind., vol. 5, 1907, p. 42.

Mueller, A. The manufacture of steel in the Girod electric furnace. Met. and Chem. Eng., vol. 9, 1911, p. 581.

Nathusius, H. Improvements in electric furnaces and their application in the manufacture of steel. Jour. Iron and Steel Inst., vol. 135, No. 1, 1912, p. 57.

Neumann, B. Electric-furnace methods in iron and steel manufacture in comparison with the ordinary metallurgical processes. Electrochem. Ind., vol. 2, 1914, p. 488.

——— Röchling-Rodenhauser induction furnace for three-phase currents. Electrochem. and Met. Ind., vol. 6, 1908, p. 458.

Osborne, C. G. A few experiments with the 15-ton Héroult electric furnace at South Chicago. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 205.

Perkins, F. C. Kjellin electric furnace at Gysinge, Sweden, for the manufacture of steel. Electrochem. Ind., vol. 1, 1903, p. 576.

Queneau, A. L. A new electric steel furnace. Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 131.

Richards, J. W. Metallurgical calculations; the electrometallurgy of iron and steel. Electrochem. and Met. Ind., vol. 5, 1907, p. 165.

——— Pig steel made directly from ore in the electric furnace. Met. and Chem. Eng., vol. 10, 1912, p. 397.

——— The electrothermic production of iron and steel, methods and furnaces. Jour. Franklin Inst., vol. 164, 1907, p. 443; vol. 165, 1908, p. 47.

——— The electrometallurgical revolution in the iron and steel industry of Norway and Sweden. Proc. Eng. Soc. West. Pa., vol. 27, 1911, p. 125.

——— The Hiorth electric steel furnace. Trans. Am. Electrochem. Soc., vol. 18, 1910, p. 191.

——— The largest electric steel works. Electrochem. and Met. Ind., vol. 7, 1909, p. 9.

——— The passing of crucible steel. Met. and Chem. Eng., vol. 8, 1910, p. 563.

Robertson, T. D. The Grönwall steel-refining furnace. Met. and Chem. Eng., vol. 9, 1911, p. 573.

Robinson, T. W. Electric steel-furnace experience at South Chicago. Met. and Chem. Eng., vol. 10, 1912, p. 372.

Rodenhauser, W. The electric furnace and electric process of steel making. Jour. Iron and Steel Inst., vol. 79, 1909, No. 1, p. 261.

Rowlands, T. Induction-furnace progress. Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 103.

Stassano, E. Note on the rotating electric steel furnace in the artillery construction works, Turin. Trans. Faraday Soc., vol. 2, 1906, p. 150.

——— The application of the electric furnace to siderurgy. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 63.

——— Treatment of iron and steel in the electric furnace. Electrochem. and Met. Ind., vol. 6, 1908, p. 315.

Stoughton, B. Notes on iron and steel and electrothermic manufacture of iron and steel. Jour. Franklin Inst., vol. 167, 1909, p. 73.

Thallner, O. The manufacture of high-grade steel in the electric furnace. Electrochem. and Met. Ind., vol. 6, 1908, p. 26.

Turnball, R. The Héroult electric steel furnace. Trans. Am. Electrochem. Soc., vol. 15, 1909, p. 139; Electrochem. and Met. Ind., vol. 7, 1909, p. 260.

Vom Baur, C. H. Electric induction and resistance furnaces for steel. Trans. Am. Electrochem. Soc., vol. 22, 1912, p. 117.

———The Röchling-Rodenhauser furnace of the Crucible Steel Casting Co., Lansdowne, Pa. Iron Trade Rev., vol. 52, 1913, p. 153; Met. and Chem. Eng., vol. 11, 1913, p. 113.

Walker, W. R. Electric furnace as a possible means of producing an improved quality of steel. Met. and Chem. Eng., vol. 10, 1912, p. 371.

Wedding, H. A modification of the induction furnace for steel refining. Electrochem. and Met. Ind., vol. 6, 1908, p. 10.

Wellman, S. I. Electric steel for rails. Met. and Chem. Eng., vol. 10, 1912, p. 372.

TIN.

Harden, J. Electric tin smelting. Met. and Chem. Eng., vol. 9, 1911, p. 453.

Wile, R. S. An electric furnace for the treatment of tin dross, concentrates from cyanide mills, and other metallurgical works. Met. and Chem. Eng., vol. 10, 1912, p. 495.

——— Reduction of tin dross in an electric furnace. Trans. Am. Electrochem. Soc., vol. 18, 1910, p. 205.

VACUUM AND HIGH-PRESSURE FURNACE.

ARSEM, W. C. Electric vacuum furnace installation in research laboratory of the General Electric Co. Ind. and Eng. Chem., vol. 2, 1910, p. 3.

——— The electric vacuum furnace. Trans. Am. Electrochem. Soc., vol. 9, 1906, p. 153.

FINK, C. G. Electric vacuum furnace installation. Electrochem. and Met. Ind., vol. 4, 1906, p. 223; vol. 7, 1908, p. 428; vol. 8, 1909, p. 96.

——— Vacuum-furnace metallurgy. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 445.

HUTTON, R., and PETAVEL, M. Electric-furnace reactions under high pressure. Electrochem. and Met. Ind., vol. 6, 1908, p. 97.

PETAVEL, M. See Hutton, R.

ZINC AND LEAD.

BETTS, A. G. Electric lead smelting. Electrochem. and Met. Ind., vol. 4, 1906, p. 169.

BLEECKER, W. F. An electrolytic method for the reduction of blue powder. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 359.

BROWN, O. W. The reduction of metal sulphides. Trans. Am. Electrochem. Soc., vol. 9, 1906, p. 109.

BROWN, O. W., and OESTERLE, W. F. The electric smelting of zinc. Trans. Am. Electrochem. Soc., vol. 8, 1905, p. 170.

ENGINEERING AND MINING JOURNAL. Electric zinc smelting. Vol. 94, 1912, p. 1109.

FITZGERALD, F. A. J. A new electric resistance furnace. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 273; Met. and Chem. Eng., vol. 9, 1911, p. 259.

——— Note on an unsuccessful furnace experiment. Trans. Am. Electrochem. Soc., vol. 20, 1911, p. 281.

FLEURVILLE, E. Electric zinc smelting. Electrochem. and Met. Ind., vol. 7, 1909, p. 468.

GIN, G. The electrometallurgy of zinc. Trans. Am. Electrochem. Soc., vol. 12, 1907, p. 117.

HARBORD, F. W. Zinc smelting at Trollhättan. Eng. and Min. Jour., vol. 93, 1912, p. 344.

INGALLS, W. R. The electric smelting of zinc ore. Eng. and Min. Jour., vol. 94, 1912, p. 7; Met. and Chem. Eng., vol. 10, 1912, p. 481; Trans. Can. Min. Inst., vol. 15, 1912, p. 101.

JOHNSON, C. F. The electric zinc-smelting furnace. Met. and Chem. Eng., vol. 10, 1912, p. 28.

JOHNSON, W. McA. Notes on electric zinc smelting. Met. and Chem. Eng., vol. 10, 1912, p. 537.

——— The art of electric zinc smelting. Trans. Am. Electrochem. Soc., vol. 24, 1913, p. 191; Met. and Chem. Eng., vol. 11, 1913, p. 582.

——— The electrometallurgy of zinc and its relation to present practice. Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 265.

KEENEY, R. M., and LYON, D. A. Possible applications of the electric furnace to western metallurgy. Trans. Am. Electrochem. Soc., vol. 24, 1913, p. 119; Met. and Chem. Eng., vol. 11, 1913, p. 577.

KOWALKE, O. L. The volatility of zinc oxide. Trans. Am. Electrochem. Soc., vol. 21, 1912, p. 557.

LOUVRIER, F. Electric zinc smelting. Met. and Chem. Eng., vol. 11, 1913, p. 603.

——— Causes of the practical nonsuccess of the electric furnace in treating zinc ores. Met. and Chem. Eng., vol. 10, 1912, p. 747.

LYON, D. A. See Keeney, R. M.

METALLURGICAL AND CHEMICAL ENGINEERING. Editorial on the condensation problem in electric-zinc smelting, vol. 10, 1912, p. 451.

——— Electric-zinc smelting in Norway and Sweden. Vol. 9, 1911, p. 673.

OESTERLE, W. F. See Brown, O. W.

PETERSON, P. E. The electric-zinc furnace. Trans. Am. Electrochem. Soc., vol. 24, 1913, p. 215; Met. and Chem. Eng., vol. 11, 1913, p. 583.

RICHARDS, J. W. The electric furnace in nonferrous metallurgy. Met. and Chem. Eng., vol. 8, 1910, p. 233.

——— The Johnson electric-zinc furnace. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 311.

SNYDER, T. F. The condensation of zinc vapor from electric furnaces. Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 317; Met. and Chem. Eng., vol. 9, 1911, p. 265.

VOGEL, J. L. F. The electrolysis of fused zinc chloride in cells heated externally. Trans. Faraday Soc., vol. 2, 1906, p. 56.

WEEKS, C. A. Melting nonferrous metals in an electric furnace. Met. and Chem. Eng., vol. 9, 1911, p. 363.

PUBLICATIONS ON METALLURGY AND MINERAL TECHNOLOGY.

A limited supply of the following publications of the Bureau of Mines is available for free distribution. Requests for all publications can not be granted, and applicants should select publications that may be of especial interest to them. Requests for copies should be addressed to the Director, Bureau of Mines.

BULLETIN 3. The coke industry of the United States as related to the foundry, by Richard Moldenke. 1910. 32 pp.

BULLETIN 8. The flow of heat through furnace walls, by W. T. Ray and Henry Kreisinger. 32 pp., 19 figs.

BULLETIN 12. Apparatus and methods for the sampling and analysis of furnace gases, by J. C. W. Frazer and E. J. Hoffman. 1911. 22 pp., 6 figs.

BULLETIN 47. Notes on mineral wastes, by C. L. Parsons. 1912. 44 pp.

BULLETIN 53. Mining and treatment of feldspar and kaolin in the southern Appalachian region, by A. S. Watts. 1913. 170 pp., 16 pls., 12 figs.

BULLETIN 54. Foundry cupola gases and temperatures, by A. W. Belden. 1913. 29 pp., 3 pls., 16 figs.

BULLETIN 64. The titaniferous iron ores in the United States, their composition and economic value, by J. T. Singewald, jr. 1913. 145 pp., 16 pls., 3 figs.

BULLETIN 67. Electric furnaces for making iron and steel, by D. A. Lyon and R. M. Keeney. 1913. 142 pp., 36 figs.

BULLETIN 70. A preliminary report on uranium, radium, and vanadium, by R. B. Moore and K. L. Kithil. 1913. 100 pp., 2 pls., 2 figs.

BULLETIN 71. Fuller's earth, by C. L. Parsons. 1913. 38 pp.

TECHNICAL PAPER 15. An electrolytic method of preventing corrosion of iron or steel, by J. K. Clement and L. V. Walker. 1913. 19 pp., 10 figs.

TECHNICAL PAPER 31. Apparatus for the exact analysis of flue gas, by G. A. Burrell and F. M. Seibert. 1913. 12 pp., 1 fig.

TECHNICAL PAPER 41. The mining and treatment of lead and zinc ores in the Joplin district, Mo.; a preliminary report, by C. A. Wright. 1913. 43 pp., 5 figs.

TECHNICAL PAPER 60. The approximate melting points of some commercial copper alloys, by H. W. Gillett and A. B. Norton. 1913. 10 pp., 1 fig.

INDEX.

A. Page.

Acheson, Edward, carborundum furnace of,
  details of 9
   development of 2
   figure showing 9
   thermal efficiency of 4
  graphite furnace of, details of 8
   figure showing 8
   thermal efficiency of 4
Acid-process furnace, thermal efficiency of 4
Albertville, Savoie, France, ferro-alloy plant at 120
Alby furnace, figure showing 111
Alloys, electrical conductivity of 188
  See also Ferro-alloys and various alloys named.
Alumina, melting point of 37
Alumina brick, thermal conductivity of 39,40
Aluminum, furnace for making, figure showing 75
   types of 75
  manufacture of, Bett's process for 80,81
   Hall process for 74
   Héroult process for 75
  price of 140
  production of, in United States 77
  specific gravity of 76
  use of, as reducing agent 134
Aluminum industry, factors governing growth of 78
Aluminum silicates, production of aluminum from 79,80
Aluminum sulphide, reduction of 81
Alundum as furnace lining 34
   objections to 34,35
Alunite, deposits of 78
  extraction of aluminum from 78,79
Ampere, definition of 186
  relations of 186
Ampere-hour, definition of 186
Anode, requirements of, for electrolytic work 27
Apatite, as source of ferrophosphorus 154
Arc furnaces, classification of 11
  See also Siemens furnace; Stassano furnace.
Arsenic in ferrosilicon, effect of 161
Ashenary, on gases in ferrosilicon 160
Ashes, wood, thermal conductivity of 40
Austria, manufacture of ferrosilicon in 155

B.

Basic-process furnace, thermal efficiency of 4
Baur, investigations of ferrochrome by 127
Bauxite, analysis of 33
  melting point of 37
  processes for purifying 73,74
  production of aluminum from 73,79
  use of, for furnace linings 32,33
Bayer process for purifying bauxite, details of 73

Page.

Becket, F. M., on manufacture of ferrochrome 133,134
  on reduction of molybdenite 149
Behren, manufacture of ferro-alloys by 132,180
Benneville, production of tungsten alloys by 180
Berthier, manufacture of ferro-alloys by 127,177
Berzelius, manufacture of ferrosilicon by 154
Betts, method of, for production of aluminum 80,81
Bibliography 190-207
Biermann, production of ferrotungsten by 177,181
Blast furnace, manufacture of ferro-alloys in 103, 135,142,143,163,164
   difficulties in use of 103
   results of 143
  thermal efficiency of 4
Bonn, Germany, cost of electric power in furnace at 70
  production of ferromanganese at 103
Bozel, France, ferrosilicon plant at, charge used in 164,165
   reducing agent used in 165
Braintree, England, electric furnace at, cost of electric power in 70
Brick dust, thermal conductivity of 40
Bridgewater, Pa., production of ferro-alloys at 106
British thermal unit, relations of 186
Bunsen, reduction of aluminum by 72
Bureau of Mines, investigations of 84,91,101
Burgess, C. F., classification of electric furnaces by 7

C.

Calcium in ferrosilicon, effect of 160
Calcium carbide, manufacture of 124,125
  use of, as reducing agent 133
Calcium phosphide in ferrosilicon, effect of 161
  use of, as reducing agent 133
Canada, manufacture of ferrosilicon in 155
Carbide furnace, development of 2
  electrode holders for, figures showing 50-54
Carbon, melting point of 37
  thermal conductivity of 40
  use of, as reducing agent 92, 128,131,132,149,161,162
   for furnace linings 33,34
  See also Charcoal, Coal, Coke.
Carbon monoxide, use of, in reduction of zinc oxide 92
Carborundum, composition of 35
  melting point of 37
  use of, for furnace linings 35
Carborundum furnace, details of 9
  development of 2
  figure showing 9
  thermal efficiency of 4
Carborundum sand, thermal conductivity of 39,40
Carnot, manufacture of alloys by 132,155,156,180
  on composition of ferromanganese 142

Page.
- Caron, experiments on ferrotungsten by 177
- Cement, thermal conductivity of 40
- "Centrifugal effect," definition of 21
  - influence of, on bath in furnace 21
- Chalmot, manufacture of silicides of iron by 157
- Chaplet furnace, details of 109
  - figure showing 109
- Charcoal, thermal conductivity of 40
  - use of, as reducing agent, relative advantages of 83
  - *See also* Carbon.
- Chromite, analysis of 34, 128
  - melting point of 37
  - smelting of, in electric furnace 128
  - use of, for furnace linings 34
- Chromite ores, analyses of 135
- Clinker, thermal conductivity of 40
- Coal, anthracite, use of, as reducing agent 135
- Coke, powdered, thermal conductivity of 40
  - use of, as reducing agent 81–84
    - disadvantages of 82, 83
  - *See also* Carbon.
- Colemanite, analysis of 126
  - use of 126
- Combustion furnace, limitations of 2, 3, 6
  - maximum temperature in 6
  - relative efficiency of 3, 4
- Conductivity, definition of 188
  - electrical, of metals and alloys 188
- Conductors, list of 188
- Conrad, W., ferrosilicon plant designed by 166
- Copper, smelting of, in electric furnace 87, 88
  - thermal conductivity of 40
  - use of, as conductor 13, 14
- Copper sulphate, electrolysis of, method used in 25, 26
- Cote-Pierron, process of, for zinc smelting 92
  - details of 98
- Coulomb, definition of 186
  - relations of 186
- Courtepin, Switzerland, ferro-alloy plant at 120
- Cowles, A. H., investigations of 2
  - smelting of zinc ores by 91
- Cowles, E. H., investigations of 2
  - smelting of zinc ores by 91
- Cowles process for reducing aluminum, details of 72, 73
- Crawford, John, on electric furnaces in Sweden 85
  - on use of coke as reducing agent 82, 83
- Crucible, proper volume of 39
  - shape of, factors governing 30
- Crucible furnace, use of, in manufacture of ferro-alloys 103, 135
- Cryolite, melting point of, reduction of 76
  - specific gravity of 76
- Crystolon as furnace lining 35
- Cuba, chromite ore from, analysis of 135
- Culley, ——, on resistance of water 188
- Current, alternating, in ferro-alloy furnace, advantages of 22, 117
    - wave of, curve showing 13
  - direct, in ferro-alloy furnace, objections to 117
  - eddy, definition of 18
    - prevention of losses from 18
- Current, regulation of 24
  - self-induced, loss of power from 18
  - three-phase, types of connections for, figure showing 24

D.

- De Laval, process of, for zinc smelting 92
- Delta connections for single-phase furnaces, figure showing 117
- Deville, reduction of aluminum by 72
- Dinas brick, analysis of 31
  - characteristics of 30, 31
- Direct heating. *See* Heating.
- Domnarfvet, electrodes used in furnaces at 62
- Dunite, reduction of 153
- Dupre, on gases in ferrosilicon 160

E.

- Eddy currents. *See* Current.
- Electric furnaces, advantages of 2, 3, 6
  - classification of 7
  - efficiency of, factors governing 12–41
  - energy required for, calculation of 28
  - internal dimensions of 29
  - limitations of 5, 6
    - causes of 5, 6
  - manufacture of ferro-alloys in 104–106, 143, 144, 164
  - operation of, conditions governing 70, 71
  - output of, factors affecting 27, 28
  - reduction of iron ores in 84, 85
  - relative efficiency of 3, 4
  - size of, relation of, to heat loss 41
  - smelting of copper ores in 87, 88
    - relative advantages of 89
  - smelting of gold and silver ores in 90
  - voltage necessary in, factors governing 29
  - *See also* various furnaces named.
- Electrical connections for furnaces, figure showing 114
- Electricity, cost of, conditions determining 67–69
  - in metallurgy, history of 2
    - processes involved in use of 1
    - value of 3
  - methods of heating with 13
- Electrode holders, construction of 48, 49
  - figures showing 107, 111
  - for carbide furnaces, description of 50
  - German, details of 53
    - figure showing 58
  - side, movable, details of 55, 56
      - figures showing 59–63
    - use of 48
      - advantage of 48
  - top, types of 50–54
      - figures showing 50–54
    - use of 47, 48
  - types of 47, 115, 116
  - water-cooled, details of 52
    - figures showing 56, 57
  - with cooling device, figures showing 51, 52
- Electrodes, arrangement of, in bundles 62
      - advantages of 62, 63
  - block, holders for, figures showing 60, 61
  - carbon, relative advantages of 42

Page.
Electrodes, conductivity of, method of increasing 63
  connections for, figures showing 63, 64
  consumption of 83, 86, 99, 100
  current density of, conditions determining 61
  dimensions of, conditions determining 60, 61
  effect of use on, figure showing 47
  efficiency of, conditions governing 43
  figure showing 107, 111
  graphite, relative advantages of 42
  joining of, electrical losses caused by 66
    methods of 65–67
      figure showing 66
  loss of energy in 42
  losses by, laws of 43, 44
  manufacture of 42
  properties of 41
  round, holder for, description of 52
      figure showing 56
  size of, calculation of formulas for 45, 46
  specially shaped, figure showing 49
  thermal conductivity of, factors governing 43
  top holders for, use of 47, 48
  types of 42
Electrolysis, application of, in electric furnace practice 25, 26
  factors involved in 26, 27
  metal liberated by, calculation of 26
Electrolytes, preparation of, prerequisites of. 26
Electro-Metals furnace, regulation of electric current in 24
Europe, growth of ferro-alloy industry in 105

F.

Farad, definition of 186
Faraday, investigations of ferrochrome by 127
Farup, P., on use of coke as reducing agent 82
Ferberite, production of ferrotungsten from 178, 179, 181, 183
Ferro-alloy furnaces, current in 117
  electrical connections in 114
  electrode holders for, figure showing 107, 111
    types of 115, 116
  essential details of 113, 115
  linings for 115
  open-top, waste of heat in 116
  single phase, connections for, figure showing 117
  three phase, connections for, figure showing 118
Ferro-alloys, commercial production of, in electric furnace 104
  definition of 102
  kinds of 103
  manufacture of, difficulties involved in 102
    electrode holder used in, details of 50
      figure showing 54
    in blast furnace, difficulties in 103, 104
    types of furnaces for 106–118
  use of, in manufacture of iron and steel 102
  See also various ferro-alloys named.
Ferro-aluminum, manufacture of 125
Ferroboron, composition of 126
  manufacture of 125, 126
  production of, in United States 106

Page.
Ferrochrome, analyses of 138
  carbon-free, manufacture of 135, 137
  characteristics of 132, 133
  grades of 138
  manufacture of 103, 104, 119, 124, 125
    cost of 139
    electrode consumption in 138
    experiments in 129–131
    furnaces used in 135, 136
    history of 127
    materials used in 128
    process of 136, 137
  price of 140
  production of, in United States 105, 106
  refining of 134, 137
    cost of 137
  uses of 140, 141
Ferromanganese, manufacture of 104, 105
    experiments in 103, 142
    furnace used in 143
    history of 141, 142
    process of 142–143
  price of 140
  production of, in United States 105
  uses of 144, 145
Ferromanganese-silicon, analyses of 146
  grades of 145
  manufacture of, methods of 145
  price of 145
Ferromolybdenum, analyses of 150
  characteristics of 149
  elimination of sulphur from 147, 148
  manufacture of, experiments in 148
    history of 146
    methods of 147, 150
  price of 140
  production of, in United States 106
  uses of 150, 151
Ferronickel, analyses of 152, 154
  composition of 151
  manufacture of 151, 153, 154
    experiments in 152
  production of, in United States 106
Ferrophosphorus, grades of 154
  manufacture of 154
  production of, in United States 106
Ferrosilico-aluminum, manufacture of 175
  uses of 175
Ferrosilico-manganese-aluminum, grades of 175
  use of 175
Ferrosilicon, characteristics of 158
  disintegration of, causes of 158, 160
    prevention of 160
  formation of gases in, cause of 158, 160, 161
  fusing point of 159
  grades of, analyses of 172
    classification of 172
  manufacture of 119, 162, 163
    charge used in 164
    furnace used in 106, 107
    history of 103, 154, 155
    in blast furnace 163, 164
    in electric furnace 104, 164
    reducing agents used in 165
    variations in cost of 173
  melting point of 159

Page.
Ferrosilicon, production of, in United States 105, 106
reduction of, with carbon.............. 161, 162
formula for........................ 161
selling price of.......................... 140
silicon content of, effect of.............. 158
specific gravity of...................... 158
curves showing...................... 159
transportation of, risks in................ 173
uses of.......................... 127, 128, 174
Ferrosilicon furnace, changing of electrodes in. 169
charges in.............................. 170
figure showing.......................... 106
labor required for....................... 171
method of charging................... 167, 168
power consumption of.................. 171
slags in analyses of..................... 170
formation of.......................... 170
tapping of.............................. 169
Ferrosilicon plant, details of............... 166, 167
elevation of, figure showing............... 168
plan of, figure showing................... 167
Ferrotitanium, manufacture of............ 175, 176
production of, in United States........ 105, 106
selling price of......................... 140
uses of................................ 177
Ferrotungsten, analyses of................ 183
manufacture of........................ 178, 179
experiments in..................... 180
history of.......................... 177
processes of..................... 182, 183
reactions in....................... 181
production of, in United States........ 105, 106
selling price of......................... 140
uses of................................ 184
Ferrovanadium, analyses of................ 185
manufacture of, methods of............ 184, 185
production of, in United States......... 105, 106
selling price of......................... 140
uses of................................ 185
Fire brick, thermal conductivity of.......... 40
Fire brick dust, heat conductivity of........ 39
Fire clay, melting point of................... 37
Fire-clay bricks, heat conductivity of......... 39
Fitzgerald, F. A. J., experiments by......... 35
on alundum furnace linings.............. 34, 35
on calcining of magnesia in electric furnace.............................. 32
on joining electrodes................... 65
France, production of ferro-alloys in.......... 155
cost of........................... 139, 173
Fremy, manufacture of ferro-alloys by..... 127, 156
Fulton, C. H., on composition of ganister ... 31
Furnace linings, construction of............. 115
life of.................................. 115
Furnace walls, insulation of................ 39, 40
materials for, heat conductivities of...... 39
thickness of, conditions governing....... 38
relation of, to heat loss............. 40, 41
Furnaces. *See* various furnaces named.

G.

Ganister, composition of.................... 31
Garnerite, reduction of...................... 153
Gas-engine power plants, cost of installing... 68
operating cost of........................ 69
Gas engines, electric power generated by, cost of.. 68
Germany, manufacture of ferro-alloys in... 105, 155
selling price of ferro-alloys in............ 140
Gin, manufacture of ferro-alloys by..... 134, 156, 181
on charge of ferrosilicon................. 164
Girod, Paul, ferro-alloy plant of, figure showing.................................. 121
plan of.............................. 121, 122
power supply of.................... 120, 121
production of...................... 122
manufacture of ferro-alloys by........... 120
on value of boron...................... 126
Girod furnace, details of.................... 110
features of............................ 16
figure showing....................... 16, 110
internal dimensions of.................. 29
regulation of electric current in.......... 24
Gold ores, smelting of, in electric furnace.... 90
Goldschmidt thermit process, manufacture of ferrotitanium by................. 176
Goutal, manufacture of alloys by... 132, 155, 156, 180
on composition of ferromanganese........ 142
Graphite, thermal conductivity of.......... 40
Greenwood crucible furnace, thermal efficiency of.............................. 4
Grönwall, experiments of.................. 2
Guichard, M., manufacture of molybdenum by.............................. 147
Guillet, L., on composition of boron steel.... 126
Gürtler, on cooling curves of iron-silicon system.............................. 157
on fusing point of ferrosilicon............ 159

H.

Hadfield, use of ferrosilicon by............... 174
Hagfors, Sweden, electric furnaces at, value of gas from........................... 86, 87
Hahe, on gases in ferrosilicon............... 160
on specific gravity of ferrosilicon......... 158
Hahn, manufacture of silicides of iron by.... 156
Hall, C. M., investigations of................ 2
process of, for producing aluminum...... 73, 74
for purifying bauxite................ 74
Hansen, method of, for production of ferroboron.............................. 126
Harbord, F. W., on zinc smelting in electric furnace............................ 93, 95
Hardanger, Norway, experiments at.......... 82
Heat, development of, in conductor, relations of......... 189
waste of, in open-top furnaces............ 116
Heat loss, relation of, to size of furnace....... 41
to thickness of furnace walls......... 41
Heat unit, equivalents of.................... 187
Heating, arc, method of..................... 16, 17
direct, by resistance, disadvantage of.... 13
indirect-resistance, furnaces using........ 15, 16
method of.......................... 15
induction, definition of.................. 14
factors governing................... 13, 14
Helberger furnace, features of............... 16
figure showing......................... 16
Helfenstein furnace, details of............... 113
figure showing......................... 114
Henry, definition of........................ 186
Hering, C., laws of electrode losses by........ 43, 44

Page.

- Hering, C., on insulation of furnace walls.... 39
  - on measure of flow of heat.............. 44
  - on "pinch effect"...................... 19
  - on proper size of electrodes.............. 45, 46
- Herlienus, A., on quality of electric pig iron. 86
- Héroult, Paul, investigations of.............. 2
  - on increasing conductivity of electrodes.. 63
  - process of, for manufacture of aluminum. 73, 75
- Heroult, Cal., electric furnaces at, control of.. 25
    - cost of power in.................. 70
    - experiments in.................. 82, 83
    - production of iron in.............. 84
- Héroult furnace, electrode holders for........ 57
  - figure showing.......................... 10
  - internal dimensions of.................. 29
  - regulation of electric current in.......... 24
- Horsepower, equivalents of.................. 187
  - relations of.............................. 186
- Hubuerite, production of ferrotungsten from. 183
- Hutton, R. S., on reduction of aluminum oxides.............................. 79, 80
- Hydroelectric power, cost of installing, conditions determining............... 67
- Hysteresis, definition of..................... 18

I.

- Imbert-Thomson-Fitzgerald, process of, for zinc smelting...................... 92
- Indirect-resistance heating. *See* Heating.
- Induction furnace, bath of, cross section of, figure showing.................... 19
  - disadvantages of........................ 15
  - electromechanical forces in.............. 19
  - elimination of pinch effect in............ 20, 21
  - essential features of.................... 15
- Induction heating. *See* Heating.
- Infusorial earth, thermal conductivity of.... 39, 40
- Ingalls, W. R., experiments by.............. 96
  - on life of retorts........................ 99
- Insulators, list of........................... 188
- Iron, smelting of, in electric furnace......... 84, 85
    - reducing agents used in.......... 81-84
  - pig, in electric furnace, quality of........ 85, 86
  - thermal conductivity of.................. 40
  - use of, in smelting zinc................ 92, 97, 98
- Iron silicides, characteristics of............ 156, 157
  - silicon content of, effect of.............. 157
- Iron-silicon system, cooling curves of, figure showing.......................... 157
- Iron turnings, use of, in manufacture of ferrosilicon............................ 164

J.

- Jacobs furnace, thermal efficiency of......... 4
- Johnson, W. M., experiments by............ 97
  - process of, for zinc smelting............. 92
- Joule, definition of.......................... 186
  - equivalents of........................... 187
  - relations of.............................. 186
- Joule's law, statement of.................... 189

K.

- Kaafjord, Norway, smelting of copper in electric furnace at...................... 87
- Kanawha Falls, W. Va., furnaces at, charge used in........................... 165
    - power consumption in.............. 138
    - production of ferro-alloys in......... 106

Page.

- Kanolt, C. W., on melting points of fire bricks. 38
- Keeney, R. M., manufacture of ferro-alloys by 128, 148, 178, 179
  - on Swedish electric furnace.............. 85
- Keigelgen, use of silicon by.................. 133
- Keller, electrode connection designed by..... 57
    - advantages of........................ 59, 60
    - figure showing....................... 64
  - manufacture of ferro-alloys by........... 145
- Keller furnace, details of.................... 108, 109
  - figure showing.......................... 108
- Kilowatt, equivalents of...................... 187
  - relations of.............................. 187
- Kjellin, experiments of....................... 2
- Kopperaasen, Norway, ferro-alloy furnace at, details of................ 111, 112, 122, 123
    - figure showing...................... 111, 112
    - plan of............................ 123, 124
    - power consumption in.............. 138
    - power supply of.................... 123
    - products of........................ 124

L.

- La Praz, Savoie, France, cost of electric power in furnace at.................... 70
- Lag of current, definition of................. 19
- Larsen, Alf-Sinding, method of, for reduction of aluminum...................... 80
- Lead ores, smelting of, in electric furnace.... 89, 90
- Lebeau, production of silicides of iron by.... 156
- Lehner, W., results of experiments of........ 147
- Lessing, electrode connection used by........ 58
- Lime, as flux................................ 129
  - as furnace lining......................... 32
  - in reduction of molybdenite.............. 149
  - melting point of.......................... 37
  - thermal conductivity of.................. 39, 40
- Lindblad, experiments of..................... 2
- Linings, for electric furnaces, neutral, kinds of 33-36
    - refractories used in................ 30
- Liquids, use of, as resistors.................. 10
- Livet, Isère, France, ferro-alloy plant at, charge used in.................. 164, 165
    - cost of electric power in............ 70
    - plan of............................ 119
    - power supply of.................... 118
    - products of........................ 119
    - reducing agents used in 165
- Lloyd, on gases in ferrosilicon................ 160
- Louis, J., electrode holder designed by....... 55
    - figure showing...................... 59
  - on power consumption in production of ferrosilicon........................ 171

M.

- McGill University, experiments at........... 96
- Magnesia, calcined, thermal conductivity of.. 40
  - electrically calcined, advantages of....... 32
  - melting point of.......................... 37
  - use of, for furnace linings................ 32
    - objections to.................. 32
- Magnesia brick, melting point of............. 37
  - thermal conductivity of.................. 39, 40
- Magnetic field, figure showing................ 14
- Matthiessen, on resistance of German silver.. 188
- Meraker, Norway, cost of electric power in furnace at........................ 70

Page.
Metals, electrical conductivity of 188
See also various metals named.
Mexico, smelting of gold and silver ores in plant in 90
Misselt, Wichelto, on thermal conductivity of insulating materials 43
Moissan, H., investigations of 16, 104, 128, 132
manufacture of ferro-alloys by. 147, 155, 156, 180
on temperature necessary for oxidation of carbon 42
Moissan furnace, description of 16, 17
figure showing 17
Molybdenite, reduction of, experiments in 148
smelting of, methods of 147
Moulden, J. C., on smelting of zinc in electric furnace 95
Mushet, investigations of ferro-alloys by 127

N.

Naske, manufacture of silicides of iron by 155-157
Nathusius, electrode holder used by, figure showing 63
Neumann, G., investigations of 127, 147-149
on production of aluminum 74
New Caledonia, chromite ores from, analysis of 135
New South Wales, analysis of chromite ores from 135
Newark, N. J., production of ferro-alloys at 106
Niagara Falls, Canada, cost of electric power at 70
Niagara Falls, U. S., cost of electric power at. 70
production of ferro-alloys at 106
Nickel, selling price of 140
Nickel silicide, composition of 153
manufacture of 153
Nonelectrolytic furnace, description of 10
Northrup, E. F., on "pinch effect" 19
Norway, manufacture of ferro-alloys in 124, 155
cost of 139, 173
reducing agent used at ferro silicon plants in 165
Notodden, Norway, cost of electric power in furnace at 70

O.

Odelberg, E., on quality of electric pig iron 86
Oedquist, Gustaf, on use of coke as reducing agent 82
Ohm, definition of 186
Ohm's law, explanation of 189
use of, in determining power factor 22, 23
Oil, crude, use of, as reducing agent 84
Olsen, H., on manufacture of aluminum 74
Osmond, F., manufacture of silicides of iron by 156
Output of electric furnace, factors affecting 27, 28

P.

Patronite, use of, in manufacture of ferrovanadium 185
Percy, investigations of ferrochrome by 127
Perkins, on increasing conductivity of electrodes 64

Page.
Petavel, J. E., on reduction of aluminum oxides 79, 80
Phalen, W. C., on experiments with alunite. 78
on bauxite mining 73
Pick, W., design of ferrosilicon plant by 166
on manufacture of silicides of iron 157
Pig iron. *See* Iron.
Pinch effect, difficulties caused by 20
elimination of, in induction furnaces 20, 21
influence of, on electric furnace 20
Pourcel, manufacture of ferro-alloys by 141, 155
Power factor, determination of 22
Price, E. F., on refining of ferrochrome 134
use of silicon as reducing agent by 133
Prieger, manufacture of ferromanganese by. 141, 142
Primos, Pa., production of ferro-alloys at 106
Pyrrhotite, roasted, production of ferronickel from 152

Q.

Quartz sand, thermal conductivity of 39, 40
Quartzite, use of, in manufacture of ferrosilicon 165

R.

Reducing agents. *See* Aluminum, Calcium phosphide, Carbon, Charcoal, Coal, Coke, Ferrosilicon, Oil, Silicon.
Refractories, acid, for furnace linings 30, 31
basic, for furnace linings, kinds of 32
for electric furnaces, selection of, conditions governing 36-38
thermal conductivity of 40
Remsheid, Germany, cost of electric power in furnace at 70
Resistance, electrical, laws of 187
of metals and alloys, variations in 188
specific, definition of 188
Resistivity, definition of 188
Resistor, definition of 7
materials used as 8
Retort furnace, thermal efficiency of 4
Retorts, relative consumption of, in zinc smelting 99, 100
Reverberatory furnace, thermal efficiency of. 4
Reynolds, experiments by 97
Rhodonite, as ore for making ferromanganese-silicon 145
Richards, J. W., on conductivity of aluminum 188
on process for purifying bauxite 73
on thermal efficiency of zinc retort 91
Rigg, Gilbert, on properties of refractory materials 36
Rjukan, Norway, cost of electric power in furnace at 70
Rossi, A. J., manufacture of ferro-alloys by 175, 176, 181, 182
reducing agent for ferrochrome by 134
Rothenau, manufacture of ferrosilicon by 155
Rumford Falls, Me., cost of electric power in furnace at 70
Rutile, cost of 177
use of, in manufacture of ferrotitanium 177

S. Page.
St. Gervais, Switzerland, ferro-alloy plant at. 120
St. Marcel, France, ferrosilicon plant at,
  charge used in 165
  reducing agents used in 165
Sarpsborg, Norway, zinc smelting at, equipment for 93
  results of 94, 95
Sault Ste. Marie, results of experiments at. 151, 152
Schaller, experiments by 78
Scheelite, production of ferrotungsten from. 181, 183
Schilowski, J., experiments by, on smelting of copper ores 88
Self-induced currents. *See* Currents.
Self-induction, definition of 18
Series furnace, details of 112
  figures showing 112, 113
Serpek process for manufacturing aluminum, details of 76, 77
Seward, use of silicon as reducing agent by.. 133
Sheffield, England, cost of electric power in furnace at 70
Shelburne Falls, Mass., cost of electric power in furnace at 70
Siemens, William, investigations of 2
Siemens furnace, details of 106, 107
  figures showing 12, 106
  operation of 107, 108
  thermal efficiency of 4
Silica, melting point of 37
Silica brick, melting point of 37
  thermal conductivity of 40
Silica sand, analysis of 30
Silicomanganese. *See* Ferromanganese-silicon.
Silico-spiegel, manufacture of 155
Silicon, in ferrosilicon, effect of 158
  use of, as reducing agent 133
Silver ores, smelting of 90
Snake River, Idaho, cost of electric power at.. 70
Snyder, F. T., on thermal conductivity of refractories 40
Solids, use of, as resistors 8, 9
Spiegeleisen, definition of 142
Stalhane, experiments of 2
Stansfield, A., experiments by 96
  on classification of electric furnaces 7
  on heat conductivity of furnace materials. 39
  on heat loss in furnaces 41
  on Moissan furnace 16, 17
Stassano, E., experiments by 2, 142
  manufacture of ferrotungsten by 178
Stassano furnace, electrode holder for, figure showing 65
  figure showing 11
Steam turbine power plants, cost of installing. 68
  cost of operating 69
Steel, chrome, characteristics of 141
  manganese, characteristics of 144, 145
  uses of 145
  manufacture of, use of ferrotungsten in.. 184
  tungsten, use of
  turnings, use of, in manufacture of ferrosilicon 164
Stephan, M., experiments of 88, 153, 154
Stodarts, investigations of ferrochrome by... 127
Strohmayer, manufacture of ferrosilicon by.. 154
Sulphur, elimination of, from ferromolybdenum 147, 148
Sweden, electric furnaces in, for production of iron 85
  manufacture of ferrosilicon in 155, 165
Switzerland, manufacture of ferrosilicon in... 155

T.

Tamman, on cooling curves of iron-silicon system 157
  on fusing point of ferrosilicon 159
Temperature, effect of, on resistance of metals 188
Thermit process for manufacture of ferrochrome 135, 137
Three-phase current. *See* Current.
Tin, smelting of, in electric furnace 101
Tone, method of, for production of aluminum. 79, 80
Trollhättan, Sweden, furnace at, cost of electric power in 70
  electrodes used in 62
    consumption of 100
  results of experimental work in. 82, 85, 86, 87
  smelting of lead ores in 89, 90
  zinc smelting in 93–95
Trondhjem, Norway, smelting of copper in electric furnace at 87
Tube furnace, details of 9
  figure showing 9
Tungsten, selling price of 140
Turkey, chromite ores from, analysis of 135
Turners Falls, Mass., cost of electric power in furnace at 70
Tyssedal, Hardanger, Norway, cost of electric power in furnace at 70

U.

Ugine, Savoie, France, ferro-alloy plant at... 120
  charge used in 164, 165
  reducing agents used in 165
  furnace at, cost of electric power in 70
United States, growth of ferro-alloy industry in 105
  production of aluminum in 77
  production of ferro-alloys in 155
    cost of 139, 173
  selling price of ferro-alloys in 140

V.

Valten, manufacture of ferrosilicon by 154
Van Linge, investigations of ferrochrome manufacture by 132
Van Norden, R. W., on electric control of furnaces at Heroult, Cal 25
Vattier, copper-smelting experiments of 87, 88
Vogt, H. L., on use of coke as reducing agent 82
Volklingen, Germany, cost of electric power in furnace at 70
Volt, definition of 186

W. Page.

Water, electrolysis of, method used in....... 25
Watt, definition of........................ 12, 186
  equivalents of........................ 187
  relations of........................ 186
  value of, in measuring flow of heat....... 44
Wattmeter, use of........................ 23
Webster, N. C., production of nickel alloys at. 153
Weston, on resistance of German silver...... 188
Williams, manufacture of ferro-alloys by..... 132, 180, 181
Wilson, T. L., investigations of.............. 2, 160
Winteler, on aluminum cells................ 74
Wolframite, production of ferrotungsten from 178, 181, 183
Wolgodine, S., on conductivity of carbon and graphite........................ 42
Wolkoff, W., experiments by, on smelting of copper ores........................ 88

Z.

Zinc, condensation of vapor from............ 99
  smelting of, in electric furnace, methods of........................ 91, 92, 93
    difficulties met in................ 99
Zinc oxide, reduction of, method for......... 96
Zinc smelting, formation of blue powder in, causes of........................ 100

Bulletin 81

DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

JOSEPH A. HOLMES, DIRECTOR

THE SMELTING OF COPPER ORES IN THE ELECTRIC FURNACE

BY

DORSEY A. LYON

AND

ROBERT M. KEENEY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

[illegible] of the provisions of its organic [illegible] made—prints a limited free

[illegible] obtained at cost price only [illegible] Printing Office, Washington, [illegible] for the sale of all [illegible] *of the Bureau of Mines.*

[illegible]:

[illegible]ments,

[illegible] Office,

Washington, D. C.

[illegible] prohibits the [illegible] additional copies must be [illegible] of this bulletin is 10

CONTENTS.

Page.

ntroduction 7
Chemistry of copper smelting 8
  Smelting of native copper ores 8
  Smelting of oxide, carbonate, or silicate ores 8
  Smelting of sulphide ores 9
    Removal of sulphur 9
      Results of smelting raw sulphide ore in a blast furnace 9
      Methods of smelting sulphide ores 10
        Reactions in the blast furnace 11
Reverberatory copper smelting 11
Substitution of the electric furnace for the reverberatory furnace 12
Smelting of native copper ores 13
  Metallurgical practice at Michigan smelters 13
    Concentration methods 13
    Smelting procedure 14
      Method of operating reverberatory furnace 14
      Treatment of slags from furnace 15
  Experimental smelting of fine Michigan native copper concentrates in the electric furnace 15
    General description of experiments 16
    Description of furnace used 17
      The crucible 17
      Walls and crucible support 18
      Electrodes and holders 19
        Regulating device 20
    Apparatus and instruments 20
    Concentrates smelted 21
    Problems of electric smelting of native copper concentrates 22
      Loss of copper 22
      Reduction of iron oxide 23
    Description of experiments 23
      Smelting concentrate No. 4 without flux 23
        Experiment No. 1 23
        Experiment No. 2 24
      Varying the acidity of the slag with silica 24
        Experiment No. 3 24
        Experiment No. 4 24
        Experiment No. 5 24
        Experiment No. 6 25
        Experiment No. 7 25
      Varying the basicity of slag with hematite 25
        Experiment No. 8 25
        Experiment No. 9 25
      Varying the basicity of slag with limestone 25
        Experiment No. 10 25
      Varying the basicity of the slag with limestone and hematite 26
        Experiment No. 11 26
        Experiment No. 12 26
        Experiment No. 13 26

Smelting of native copper ores—Continued.

Experimental smelting of fine Michigan native copper concentrates in the electric furnace—Continued.

Description of experiments—Continued.

Page.
- Continuous smelting.......... 26
  - Experiment No. 14.......... 26
- Results of experiments.......... 27
- Discussion of results.......... 29
  - Copper losses.......... 29
    - Experiments with concentrate No. 4.......... 31
    - Experiments with concentrate No. 3.......... 32
  - Iron in the metallic copper.......... 32
    - Factors affecting reduction of iron by the electrode.......... 33
    - Effect of base used.......... 34
    - Effect of alumina.......... 34
    - Conclusions.......... 34
  - Power consumption.......... 35
  - Operation of furnace.......... 38
  - Electrode consumption.......... 39
- Utilization of slags for production of ferrosilicon.......... 39
  - Experiment with slag and coke.......... 40
  - Experiment with slag, quartz, and coke.......... 41
  - Other experiments.......... 41
  - Discussion of results.......... 41
- Conclusions.......... 42
- Proposed process for electric smelting of fine native copper concentrate.......... 43
  - Description of furnace.......... 43
  - Comparison of proposed and present methods.......... 45
  - Cost of electric smelting compared with cost of present methods.......... 46
- Smelting of sulphide copper ores.......... 48
  - Ordinary copper blast-furnace smelting.......... 48
    - Principal features of the process.......... 48
    - Removal of sulphur.......... 49
    - Possibility of substituting the electric furnace.......... 50
      - Losses of metals.......... 51
  - Data on experimental smelting of raw sulphide, oxidized, and carbonate ores.......... 53
    - Experiment by Vattier.......... 54
      - Method and results of test.......... 54
      - Discussion of results.......... 55
    - Experiments by Schilowski.......... 56
      - Smelting mixtures of raw and roasted ore.......... 56
        - Discussion of results.......... 57
      - Recovery of arsenic from raw ore.......... 57
        - Method of test.......... 58
        - Results of test.......... 58
    - Experiments by Wolkoff.......... 58
      - Smelting ore and iron oxide to obtain matte.......... 58
      - Smelting ore and matte to obtain metallic copper.......... 58
    - Experiments by Stephan.......... 59
      - Smelting nonferrous ore in the electric furnace.......... 59
        - Conclusions of Stephan.......... 60

Smelting of sulphide copper ores—Continued. Page.
Experimental smelting of sulphide ores in the electric furnace........... 60
Ores treated.. 60
Methods used and results of tests........................... 61
Discussion of results.. 62
Smelting conditions, sulphur volatilization, and ratio of concentration. 62
Copper, gold, and silver losses, and low-grade matte as a collector...... 63
Electrode consumption.. 64
Power consumption.. 64
Conclusions.. 65
Comparison of electric furnace with reverberatory furnace and blast furnace. 65
Semipyritic smelting of sulphide ores.. 66
Principal features of the process.. 66
Substitution of electric heat for heat derived from coke................ 67
Behavior of a charge smelted without coke........................ 68
Effect of coke in the blast furnace.. 68
Reactions in the electric furnace.. 69
Comparison of electric blast furnace with the copper blast furnace for semipyritic smelting.. 69
Metallurgical considerations.. 69
Mechanical considerations.. 70
Comparison of costs.. 70
Cost of plant.. 71
Amount ot electrical energy required to replace coke................ 71
Cost of smelting.. 72
The use of the electric blast furnace in the smelting of pyritic ores...... 73
Conclusion.. 75
Publications on mineral technology.. 77

TABLES.

Page.
TABLE 1. Results of smelting concentrate No. 3 with limestone flux, experiment No. 10.. 27
2. Results of smelting fine Michigan native copper concentrates in the electric furnace.. 28
3. Results of smelting copper sulphide ores in the electric furnace, experiments 1 to 5.. 61

ILLUSTRATIONS.

Page.
FIGURE 1. Elevation of experimental furnace.. 18
2. Plan of experimental furnace.. 19
3. Elevation of electric furnace for smelting native copper concentrates 44
4. Plan of electric furnace for smelting native copper concentrates.... 45
5. Elevation of electric blast furnace.. 52
6. Plan of electric blast furnace.. 53

THE SMELTING OF COPPER ORES IN THE ELECTRIC FURNACE.

By Dorsey A. Lyon and Robert M. Keeney.

INTRODUCTION.

This bulletin is one of a series dealing with the application of the electric furnace to the smelting of ores and the manufacture of alloys, and is published by the Bureau of Mines in the endeavor to increase efficiency in metallurgical processes.

The bulletin presents, first, a critical discussion of the possibility of smelting copper ores in the electric furnace; second, the results of the experimental work of other investigators on the electric smelting of copper; third, the results of experiments by the authors on the electric smelting of native copper concentrates and sulphide copper ores; and, fourth, a comparison of the electric furnace with the blast furnace and reverberatory furnace for copper smelting.

Before considering the electric smelting of copper ores the reader should understand that the electric furnace was not developed as a competitor of the combustion furnace, but for the purpose of doing high-temperature work that can not be done in the combustion furnace, and for the treatment of ores from deposits that are in regions where fuel is scarce and costly but hydroelectric power is comparatively cheap, as in Chile, and in certain parts of Canada, the United States, and Mexico.

Furthermore, it is not the object of this report to try to prove that the electric furnace should replace the reverberatory or the blast furnace, as used at present in smelting copper ores, but to show that the electric furnace may be used with advantage in localities where conditions are not favorable to the use of the reverberatory or the blast furnace.

For example, otherwise valuable ore deposits may be situated in a district so remote from, or inaccessible by, railway that the cost of getting coke for smelting, or of transporting the ore to a smelter, is prohibitive. If there is sufficient water power at hand, from which electric power can be developed at a reasonable cost, and this electric power is used for smelting the ore in an electric furnace, with subsequent bessemerizing, if necessary, the concentrated product may be valuable enough to render treatment of the ore possible. Or, the deposits may be accessible by railroad and yet the cost of fuel may be too great for smelting by the ordinary methods, whereas, on the other hand, hydroelectric power can be developed in the district at a low cost. By the use of the electric furnace such ores may be smelted cheaply enough to make their treatment feasible.

The possibilities being as stated, a brief comparative study of the problem is presented for the purpose of aiding those interested in the subject in determining whether it would be possible metallurgically, and feasible commercially, to use the electric furnace in those localities where, by reason of costly fuel, the cost of operating a reverberatory or blast furnace for smelting copper ores is either excessive or prohibitive.

The main points to be considered regarding the electric smelting of copper ores are whether the ores can be treated as successfully in an electric furnace as in a combustion furnace, and if so, whether they can be smelted at a reasonable cost.

CHEMISTRY OF COPPER SMELTING.

The objects sought in copper smelting may be summarized as follows: (1) To concentrate the copper into metal carrying any precious metals that may be present, if a native copper or an oxide ore is to be smelted, or into a matte, if a sulphide ore is to be treated, and (2) to remove, as slag, the excess of iron and gangue materials.

In general, there are three classes of ores that have to be considered in copper smelting, namely, native copper, the oxides, silicates, and carbonates, and sulphide ores.

SMELTING OF NATIVE COPPER ORES.

From the manner of occurrence of native copper, the smelting of native copper, or a native copper concentrate, resolves itself into the melting of the ore, or concentrate, and the separation of the metallic copper from the gangue through the difference in their specific gravities. After removal of the slag a further refining of the black copper obtained from the melting is necessary. The smelting of native ore is the simplest form of copper smelting. The electric furnace is especially adapted to simple melting in a neutral atmosphere, and appears to have particular application in this phase of copper smelting, especially the smelting of fine concentrates, as shown by recent experiments of the writers.

SMELTING OF OXIDE, CARBONATE, OR SILICATE ORES.

The process of smelting oxide, carbonate, or silicate ores of copper consists simply in melting the ores in the blast furnace with coke, thus reducing them to metallic copper. The separation of the slag and metal is an important feature of the process and the supply of coke must be carefully regulated to prevent reduction of iron by any excess carbon. The furnace atmosphere is reducing and not neutral. Such an atmosphere is easily obtainable in the electric furnace, and it is used in the electric smelting of iron. The experiments of Stephan, to be described later, also show the possibility of using a reducing atmosphere in the electric furnace.

SMELTING OF SULPHIDE ORES.

The smelting of sulphide ores presents additional complications. In order to concentrate the copper and any precious metals into a matte, it is first necessary to eliminate from the ore the sulphur, or as much of it as may be necessary, in order to obtain the desired results, and to cause the resultant oxides to unite with silica, which may either be present in the ore or may be added, preferably in the form of siliceous ore, to make a slag.

REMOVAL OF SULPHUR.

As pointed out by Peters,[a] when fused in a reducing atmosphere certain of the sulphides, such as Cu_2S, FeS, PbS, etc., melt down without change, while the very common and important mineral, pyrite, loses about one half of its sulphur, which is driven off as sulphur in the shape of yellowish fumes, which will deposit a coating of brimstone on a cool surface.

Peters also states that—

> The only two sulphides of much interest to the metallurgist, which lose a portion of their sulphur by heat alone in the manner just described, are (1) pyrite (FeS_2), which is assumed to lose one-half of its contents in sulphur by mere heating without air; and (2) chalcopyrite ($Cu_2S.Fe_2S_3$) which (as generally assumed by metallurgists) is composed of one-third copper, one-third iron, and one-third sulphur, and loses (by melting without air) one-third of its sulphur, or one-ninth of its entire weight.

This quotation is given in order to show clearly and concisely that there would be no object in simply melting sulphide ores in an electric furnace. That is, if this were done, only an altered form of the ore would result, somewhat concentrated, to be sure, through the loss of the elemental sulphur, but not concentrated enough.

RESULTS OF SMELTING RAW SULPHIDE ORE IN A BLAST FURNACE.

Peters gives the following example in order to illustrate the concentration effected by smelting in a blast furnace:

> Assume that you wish to smelt 100 pounds of a sulphide ore containing no earthy gangue rock, and consisting solely of a mixture of pyrite, chalcopyrite, and a little galena. It assays 35 ounces silver per ton and carries 6 per cent copper and 4 per cent lead. Neglect for the moment the inevitable metal losses in smelting, and assume (as the practical metallurgist generally does) that the pyrite consists of one-half

---

[a] Peters, E. D., Principles of copper smelting, 1907, p. 100.

iron and one-half sulphur, and that chalcopyrite consists of one-third each of copper, iron, and sulphur.

He then makes the necessary calculations to determine the weight of the matte that would be produced if this ore were to be smelted in a blast furnace, and from the results obtained constructs the following table:

Theoretical weight of matte produced by smelting 100 pounds of mixed sulphides.

Mineralogical composition of ore.	Weight of ore.	Chemical composition of ore.				Loss by smelting (S).	Remaining to form matte.				Total weight of matte.
		Fe.	Cu.	S.	Pb.		Fe.	Cu.	S.	Pb.	
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Pyrite	77.36	38.68	....	38.68	......	19.34	38.68	......	19.34	......	58.02
Chalcopyrite	18.00	6.00	6.00	6.00	......	2.00	6.00	6.00	4.00	......	16.00
Galena	4.64	....	....	.64	4.00	....	....	......	.64	4.00	4.64
Total	100.00	....	....	....	......	21.34	44.68	6.00	23.98	4.00	78.66

As stated by Peters, this calculation shows that if 100 pounds of mixed sulphides were to be smelted in the blast furnace the matte would weigh 78.66 pounds, or a concentration of $100 \div 78.66 = 1.27$ would be obtained, and only 1.27 tons of ore would be smelted into 1 ton of matte, which is an unsatisfactory and unprofitable degree of concentration.

METHODS OF SMELTING SULPHIDE ORES.

Such being the case, the smelting of sulphide copper ores resolves itself into one of the three following methods, or a combination of them, in order to effect the removal of sulphur and a desirable concentration:

(1) Oxides and sulphides are mixed in such proportions that the reactions necessary to effect the desired degree of concentration will take place.

(2) Sulphide ores are roasted, thus converting them into oxides, or partly so, depending on the degree to which the roasting is carried out, and are then melted in a suitable furnace. By the preliminary removal of sulphur to the desired degree, the excess iron and the gangue materials present may then be eliminated in the furnace as slag, for it is to be remembered that sulphur which is present in the charge during the melting will combine with the copper, and that any sulphur in excess of the amount necessary to satisfy the copper will unite with the iron; the remainder of the iron present as iron oxide (FeO) will unite with silica to form slag. The concentration of the copper and precious metals into a matte is thus brought about.

(3) As roasting the ore is an additional step in the process of concentration it is to be avoided if possible, and the desired oxidation of the sulphides accomplished in the blast furnace by means of the

oxygen of the air that is forced into the furnace through the tuyères. This is what the modern copper blast furnace does; it combines the functions of roasting and smelting. In other words, it oxidizes and smelts simultaneously, and also utilizes the heat that is generated by the oxidation of the sulphur and iron. This utilization of the heat generated by the oxidation of the iron and sulphur is termed pyritic smelting, although, as will be shown later, true pyritic smelting involves the smelting of sulphide ores solely by the heat arising from their own oxidation, without the addition of any carbonaceous fuel.

REACTIONS IN THE BLAST FURNACE.

In order to illustrate what takes place in a blast furnace smelting sulphide ores, assume that the charge is made up of silica, pyrite, and chalcopyrite. The shaft may be divided into two zones, namely, the preheating zone, and the oxidation and fusion zone, it being understood, of course, that there is no sharp line of demarcation between the two.

Reactions in preheating zone.—The behavior of the main constituents of the charge in passing through the preheating zone is as follows:

(1) Silica (SiO_2) remains unaltered.

(2) Chalcopyrite ($Cu_2S.Fe_2S_3$) loses about one-fourth of its sulphur as elemental sulphur and becomes a mixture of Cu_2S and FeS.

(3) Pyrite (FeS_2) loses about one-half of its sulphur and becomes FeS and then, finally, Fe.FeS.

Reactions in oxidation and fusion zone.—The reactions that take place in the oxidation and fusion zone are as follows:

(1) Chalcopyrite (Cu_2S and FeS compound) melts as soon as it has descended to a point where the temperature is high enough, a comparatively moderate temperature.

(2) The sulphur in the pyrite (Fe.FeS compound) is partly burned by the oxygen of the blast to SO_2. That which remains unburned from lack of oxygen passes through the oxidizing zone and enters the matte.

REVERBERATORY COPPER SMELTING.

The objects sought and the methods used in the smelting of copper ores have been outlined. The next point to be considered is the manner in which the smelting of copper ores is conducted.

Inasmuch as copper ores are smelted in one of two ways—that is, either in a reverberatory or in a blast furnace—it will first be necessary to ascertain if the conditions essential for the successful conduct of these two methods can be attained in the electric furnace.

As stated by Peters,[a] "the one fundamental and preeminent duty of the reverberatory type of furnace is to produce a smelting temperature so that the ore may become liquid, and thus be able to separate into slag and matte." As regards this discussion, the reverberatory furnace is used for the smelting of ores and concentrates that can not be successfully treated in a blast furnace. As Peters has shown:

---

[a] Peters, E. D., Principles of copper smelting, 1907, p. 170.

> The manner in which the heat from the fuel is applied in the reverberatory method of smelting, though much improved in modern practice, is a peculiarly wasteful one, as the mere rapid passing of a flame over the surface of a layer of ore resting upon a comparatively cool hearth is a particularly incomplete way of transferring heat from the flame to the ore particles, especially as the latter are usually poor conductors of heat.
>
> The very large surface of walls, arch, flue, stack lining, etc., is in just as favorable a position for being smelted as is the ore itself, and in spite of its refractory composition, needs frequent repairs and renewals.
>
> Such a method could only originate in a district possessing cheap flaming coal and inexpensive refractory materials, and Swansea (where the process originated) has these in abundance.
>
> The reverberatory process is but little complicated by the active extraneous agents which exert so marked an effect upon the chemistry of the blast-furnace smelting of roasted ores, and the pyrite smelting of sulphide ores, namely, carbon in the one case and oxygen in the other.
>
> Speaking in a broad general sense the ore in the reverberatory smelting furnace is subjected to neither of these influences to any marked degree, and it is thus enabled to work out its own salvation under the influence of heat alone. Such chemical reaction as takes place in the ore mass during the smelting results almost entirely from the behavior of substances already contained in the ore and is affected by the mutual action of the various constituents of the charge itself. This renders the chemical part of the operation unusually simple and enables the smelter to concentrate his efforts upon developing the high temperature essential to the complete fusion of the ore.

SUBSTITUTION OF THE ELECTRIC FURNACE FOR THE REVERBERATORY FURNACE.

If, then, as Peters states, "the proper function of the reverberatory furnace, in smelting copper ores, is to generate heat as rapidly as possible," there is no apparent reason why copper ores can not be smelted equally well in an electric furnace, and perhaps even more advantageously; for, as pointed out by Peters, and as is well known, the thermal efficiency of the average reverberatory furnace is only 5 to 8 per cent, although an efficiency of about 20 per cent is obtained in the large reverberatory furnaces at Anaconda, whereas an electric furnace for smelting copper ores that are suitable for reverberatory smelting would probably have an efficiency of 70 per cent. Chemically, the only possible disadvantage in the use of such a furnace would be the effect of the carbon of the electrodes upon the iron oxide in the charge with which the electrodes might come in contact, and which would result in (1) the loss of electrode; (2) the production of metallic iron, which, if metallic copper was desired, would cause a low-grade product, and increase the cost of refining, or if a matte was desired might necessitate reconcentration; and (3) the loss of electrical energy, due to the additional heat consumed if there were much reduction of iron by the carbon of the electrodes.

As the reverberatory furnace, whether used for smelting sulphide, oxidized, or native copper ores, is essentially a means of melting, for comparison with the reverberatory, the results obtained in the smelting of native copper ores in the electric furnace will serve to clear up for sulphide or oxide ores the three points above mentioned—namely, the loss of electrodes, the production of metallic iron, and the loss of electric energy.

The slags would be somewhat similar in each case. The atmosphere of an electric smelting furnace charged with sulphide ore would not be as neutral as that of an electric furnace charged with native copper ore, because the liberation of sulphur and the formation of sulphur dioxide tend to dilute the air and to reduce its oxygen content, making it sufficiently reducing to prevent the consumption of the electrodes by oxidation. If the electric furnace was not kept closed, considerable sulphur dioxide might be formed, which would possibly be reduced in part by the carbon of the electrodes. Even with any reduction of sulphur dioxide the electrode consumption would be probably less for sulphide ores than for native copper ores. The results of experiments by the authors confirm this statement. In a furnace charged with native copper concentrates of the grade given in Table 2, the maximum electrode consumption in 14 experiments was 48 pounds of graphitized carbon per ton of charge, the minimum was 22.1 pounds, and the average was 34.5 pounds. In the same furnace, with mixtures of sulphide, oxide, and siliceous ores, a matte being the product, the maximum electrode consumption for 20 runs was 60 pounds, the minimum was 10.8 pounds, and the average was 23.3 pounds.

SMELTING OF NATIVE COPPER ORES.

METALLURGICAL PRACTICE AT MICHIGAN SMELTERS.

Copper smelting practice in Michigan differs considerably from that of smelters in the Western States, in that instead of the production of matte and eventually blister copper from sulphide ore, copper [a] is produced directly by melting concentrates and masses containing native metallic copper. The black copper obtained is subsequently refined, and the slags obtained during the operation are resmelted.

CONCENTRATION METHODS.

The concentrates are obtained from the concentration of conglomerate or amygdaloid ores. Before concentration these ores contain from 1 to 3 per cent of copper and some native silver. The amygdaloid is high in silica, whereas the conglomerate contains more iron than silica. The milling treatment preliminary to smelting consists of crushing with breakers and steam stamps or Hardinge mills and concentration on jigs and tables until a coarse concentrate is obtained containing 60 to 80 per cent copper. Most of the coarse native silver is removed in concentration. Large masses of copper are cleaned of gangue and smelted directly. At one smelter these concentrates were separated into three grades:[a] No. 0, mass copper, containing from 65 to 70 per cent copper; No. 1, coarse concentrate and some mortar discharge, averaging about 75 per cent copper; and No. 2, fine concentrate, containing 10 to 35 per cent copper. This research was conducted on material resembling the No. 2 grade.

---

[a] Conant, H. D., Copper smelting in Michigan: School of Mines Quart., vol. 32, 1911, p. 285; Canadian Engineer, vol. 21, 1911, p. 246.

SMELTING PROCEDURE.

There are two general methods of procedure in smelting these concentrates. In one method the mass copper and coarse concentrate are charged into a reverberatory furnace and melted down without any fluxes; the slag is skimmed off as fast as it is formed and the copper tapped into another reverberatory furnace for refining. In the second method melting and refining are carried on in the same furnace. Formerly the fine concentrate, No. 2, was mixed with lime and briquetted for smelting in the blast furnace, but now at some smelters this material is first agglomerated in a reverberatory furnace and later smelted in the blast furnace.

Up to 1904 the largest reverberatory melting furnaces in operation in the district had a hearth area of 17 by 28 feet and a capacity of 200,000 pounds per charge, which, because of the cycle of operation, is practically the capacity for 24 hours.[b] At present furnaces are in use having a hearth area of 16 feet by 35 feet and a capacity of 300,000 pounds per charge. The largest reverberatory refining furnaces have a hearth 13 feet wide by 17 feet long.

METHOD OF OPERATING REVERBERATORY FURNACE.

The cycle of operation in smelting native ore is as follows:

A reverberatory furnace is charged, say, at 4 p. m., with concentrates and mass copper. After slag begins to form the charge is skimmed every 2 hours for a period of 15 hours, after which the bath is oxidized by blowing air on it or into it with an iron pipe as a carrier or tuyère. This oxidation removes arsenic and other impurities and oxidizes some of the copper to suboxide of copper, Cu_2O. The molten bath at this time contains about 95 per cent of metallic copper and about 5 per cent of cuprous oxide. The oxide is then reduced by poling with green wood and charcoal. Casting is commenced about 1 p. m. and finished about 3 p. m. The furnace is repaired if necessary and is ready for the next charge at 4 p. m.

---

[a] The western metallurgical field; copper smelting in Michigan: Met. and Chem. Eng., vol. 11, 1913, p. 12.

[b] Austin, L. S., Recent copper smelting at Lake Superior: Eng. and Min. Jour., vol. 81, Jan. 13, 1906, p. 82.

The completion of the process of oxidizing with air is determined by the electrical conductivity and fracture of a test piece. Copper refined from native copper concentrates must be coarsely crystalline to have a conductivity of 100 per cent, whereas electrolytic copper of 100 per cent conductivity may be only finely granular. Poling is complete when a test button of the metal sets with a level surface.

TREATMENT OF SLAGS FROM FURNACE.

The slags from the reverberatory furnace have a very high copper content, but if an attempt is made to reduce it the purity of the product is impaired. The slags have to be retreated in any case, so the percentage of copper in them makes little difference. Reverberatory slags contain from 10 to 30 per cent copper, the content being higher toward the end of the skimming process. Slag from amygdaloid ore is acid and contains 40 per cent SiO_2 and 20 per cent FeO, whereas slag from conglomerate ore is basic and contains 25 per cent SiO_2 and 45 per cent FeO.

These reverberatory slags are remelted in a low-pressure blast furnace with anthracite coal or coke as reducing agent and fuel, and limestone, iron oxide, or silica as a flux. The furnace is run with a slag containing 33 per cent SiO_2, 33 per cent FeO, and 20 per cent CaO, which is a fusible and liquid slag. The slag runs continuously from the furnace and contains 0.6 to 0.8 per cent copper. If the production of a cleaner slag is attempted the iron content of the product is increased, owing to the extra reducing material and higher temperature used. The metal produced contains 90 to 95 per cent copper and is retreated in a reverberatory furnace.

The blast furnace is rectangular in cross section, being 40 to 48 inches wide at the tuyères and 8 to 12 feet long. The crucible is lined with fire brick incased in a steel shell, and the shaft, which is 7 to 10 feet high, consists of steel water jackets. No forehearth is used. A blast pressure of 3 to 4 ounces is used with a production of about 72 tons of copper per 24 hours. With a higher pressure there is greater loss of copper in the slag, owing to more rapid driving of the furnace.

The refined product from the reverberatory furnace is cast into various sizes and shapes of ingots for marketing, but if it contains much silver it is cast into anodes for electrolytic refining.

EXPERIMENTAL SMELTING OF FINE MICHIGAN NATIVE COPPER CONCENTRATES IN THE ELECTRIC FURNACE.

For the purpose of investigating the feasibility of smelting fine Michigan native copper concentrates in the electric furnace instead of the reverberatory furnace, the following experiments were conducted by the writers.

The objects of these experiments were: (1) To note the effect of variation of the proportions of the three main slag constituents—silica, ferrous oxide, and lime—on the power consumption, the operation of the furnace, and the purity of the copper produced; (2) to ascertain the extent of iron oxide reduction caused by the graphite electrode; (3) to compare the results of intermittent smelting with those of continuous smelting; and (4) to study the feasibility of using the slag produced in copper smelting for the manufacture of ferrosilicon in the electric furnace.

GENERAL DESCRIPTION OF EXPERIMENTS.

The experiments were divided in six series, based on different variables in the slag-forming components of the charge. Fourteen experiments were made in all, grouped as follows: In series 1, the slag was formed from the natural gangue of the concentrate; in series 2, the acidity of the slag was varied by the addition of silica; in series 3, the basicity of the slag was varied by the addition of Lake Superior hematite; in series 4, lime was used instead of iron ore as a base; in series 5, the basicity of the slag was varied by the addition of lime and hematite; and in series 6, the furnace was charged at intervals and kept full during the run, and the metal tapped at intervals.

In all of the experiments the furnace was operated as a resistance furnace as far as possible in order to keep down the volatilization of the copper. There was arcking at the start of a run before the charge became molten, and in several runs arcking occurred at intervals during the experiment, but not for a long period of time. In all experiments, except those of series 6, the furnace was charged intermittently—that is, after starting the charge was added gradually—and all of it was completely melted before tapping. As far as possible, the furnace was tapped cleanly after each run. Any slag left in the furnace after tapping was removed by balling in the furnace in a manner similar to that used in the puddling process. Slag adhering to the walls was allowed to remain there.

In the operation of an experimental electric furnace, except on a very small scale, where tapping can not be done, it is not advisable to go to extremes to obtain an absolutely clean discharge of the molten products. To remove entirely all metal and slag, especially slag, one of two procedures must be followed: Either the charge, after becoming molten, is superheated to remelt any material that has adhered to the cooler parts of the walls, or, when the furnace has cooled off, this material is chiseled off. Either procedure results in a partial or complete destruction of the furnace lining, making a new one necessary. If the charge is superheated, the high temperature results in the brick walls becoming pasty and gradual dripping of the softened brick into the slag. One brick may be more exposed than the others and gradually be completely melted, and, aside from causing injury to the lining, materially alter the composition of the slag.

The prolonged heating may also cause volatilization of the copper, although this is not so likely to occur after the copper has been smelted down and covered with a bath of slag, as during the melting period. The prolonged heating also caused a much higher power consumption than would occur in practice, as in practice the accretions and the hangings would not affect this item after the furnace was running regularly and continuously. Chiseling out the furnace is impractical, because of the time consumed and on account of the destruction of the lining. For these reasons the furnace was built with a high degree of slope on the bottom toward the tap hole, and tapped as cleanly as possible through this hole. As a result, some of the runs show a considerable deficiency in the quantity of metal tapped as compared with the calculated amount in the charge, and some an excess; although the greatest discrepancy is in the slag. In some runs the amount of material tapped checks very closely with that charged.

DESCRIPTION OF FURNACE USED.

An electric furnace of the Siemans type is the best suited for laboratory experimental smelting of ores. A furnace of this type, as shown in figures 1 and 2, was used in these experiments.

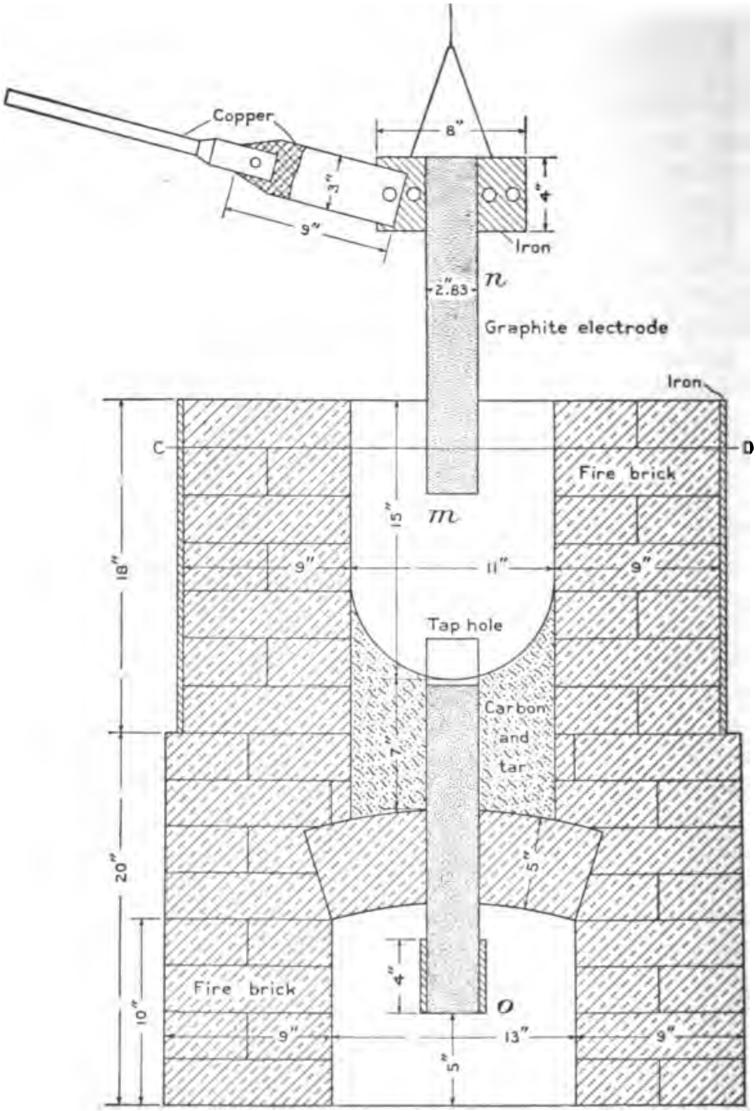
The furnace had a square crucible, *m*, lined with fire brick. The current passed into the crucible through an upper graphite electrode, *n*, then through the charge, and then through another graphite electrode, *o*, placed in the bottom of the furnace, which was made of carbon. The exterior shell of the furnace was of fire brick. The bricks were held together by iron bands, which could be adjusted for expansion. The crucible was roofed with fire-clay tiles during some experiments, in others the roof was discarded. The upper electrode was hung so as to extend vertically into the center of the crucible. No attempt was made to keep the joints in the roof tight, so that gas escaped around the electrode. Part of the tile roof was put on before charging and the opening was completely closed when all of the charge had been added. There was one tap hole at the bottom of the crucible, in the middle of one side.

THE CRUCIBLE.

The crucible was 11 inches square and its walls were vertical. The carbon bottom was tapered up about 4 inches around the walls, so that the lowest part of the bottom was about 4 inches square. The depth of the crucible was 15 inches on the average, but varied a little with different linings. The total volume of the crucible was approximately 1,600 cubic inches, but this was varied slightly from time to time as convenient.

WALLS AND CRUCIBLE SUPPORT.

The crucible was supported on an arch of fire brick set on two brick bases, each 2 feet 7 inches by 9 inches in section, and 10 inches high to the base of the arch. The arch was of 1 foot 1 inch span. The outside dimensions of the furnace at the bottom were 2 feet 7 inches by 2 feet 7 inches. These dimensions extended up to a height 1 foot 8 inches above the floor, on a level with the end of the tap hole,



SECTION A-B

FIGURE 1.—Elevation of experimental furnace.

which was 4 inches lower than the bottom of the crucible. The brick walls surrounding the crucible were 2 feet 5 inches square and 1 foot 6 inches high, making the total height of the furnace 3 feet 2 inches. An iron plate would have been better than the arch of brick, but to have procured one would have involved considerable expense and loss of time.

ELECTRODES AND HOLDERS.

The upper electrode was of Acheson graphite and was 2 inches square and 36 inches long. The lower electrode was of the same cross section and material but was 18 inches long. The part above the top of the arch was embedded in a mixture of ground electrode stumps, or coke, made plastic with tar. This material covered the upper end of the electrode to a depth of 1 inch and extended up on the walls of the furnace. The lower end projected below the arch to within 5 inches of the floor. The electrode was supported at first by an iron clamp embedded in the bricks but later simply by pressure of the bricks and the carbon mass around it. The cross-sectional area of the electrode was, of course, 4 square inches. Current was conducted to the electrode by two insulated copper cables 1 inch in diameter. The cables extended 30 feet to four copper bus bars 4 inches by 1 inch in cross section, which extended 30 feet to the switchboard where all electrical readings were taken.

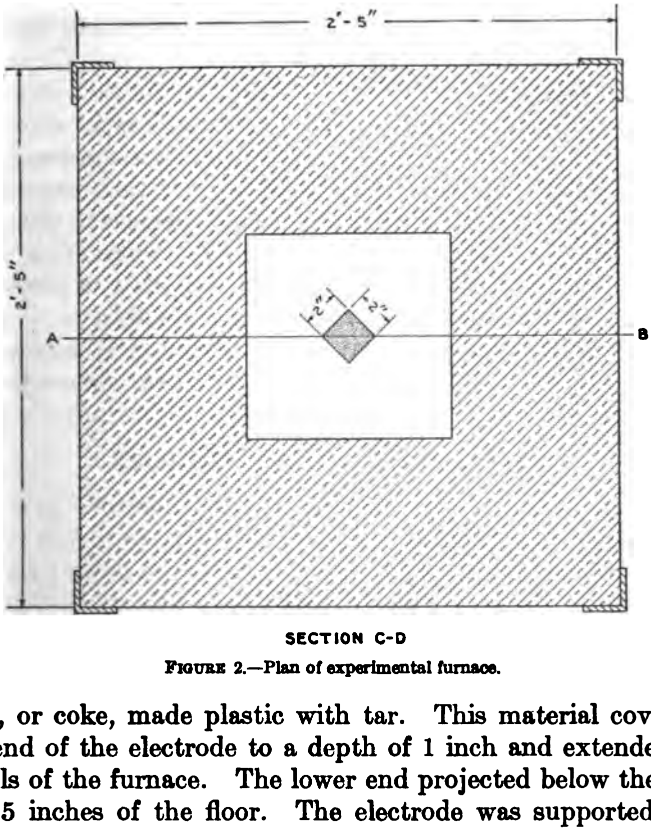


FIGURE 2.—Plan of experimental furnace.

The upper electrode holder consisted of two iron plates 4 inches wide by 8 inches long bolted together around the electrode. During some of the experiments this holder was connected to the circuit by a plate which held the loose wire of the connecting cable against the holder. This connection did not work well with high amperages, owing to short circuits burning out the wires and on account of the heating of the holder from the heat of the crucible. Later a copper plate 3 inches wide and 9 inches long was bolted to the iron holder and connected at the other end with a lug soldered in the cable. This arrangement gave complete satisfaction, as the lug was far enough from the crucible to prevent melting of the solder. The bottom connection was made by clamping the loose ends of the cable between the holder and a plate bolted to the holder, as was first used for the upper holder.

REGULATING DEVICE.

The upper electrode was suspended by flexible copper wire, running over a pulley attached to a steel crosspiece, which was set on a wooden framework 7 feet 6 inches high. The wire was then wound around a loose horizontal pipe, set at the rear of the furnace, and the electrode counterbalanced by attaching weights to the wire. This makes a simple and satisfactory device for hand regulation of electrodes in small furnaces, very close adjustment being possible.

For holding tight the upper section of the furnace, 2-inch channel irons were set on the corners and around them were placed two 1-inch strips of sheet iron.

APPARATUS AND INSTRUMENTS.

Single-phase current was received in the laboratory at a voltage which could be varied on the primary side from 440 to 550 volts with a frequency of 60 cycles. The voltage was stepped down by a 75 kilovolt ampere, single-phase transformer. The primary windings of the transformers were so adjusted and connected with switches and a voltage regulation box that the voltage could be regulated within three ranges, as follows: High voltages, ranging from 120 to 300 volts, by 12-volt steps; medium voltages, 60 to 150 volts, by 6-volt steps; and low voltages, 30 to 75 volts, by 3-volt steps. On the primary side there was a 300-ampere rheostat and a main switch fitted with a spring. On the secondary side there were two main switches and numerous voltage regulation switches.

The instruments used in taking readings were a Thomson high-torque, watt-hour meter set in the primary circuit; a Keystone indicating wattmeter, with a range of 100 kw., connected in the primary circuit; two Keystone alternating-current ammeters, with a range of '00 amperes, connected in the primary circuit, and a Keystone alternating-current voltmeter, the lower scale having a range of 100 volts and the upper scale a range of 500 volts, connected for both primary and secondary circuits. These instruments were set on a switchboard so situated that the current was conducted from 60 to 80 feet by bus bars and cables to the furnace.

Tappings were made in cast-iron molds, 19 inches long by 5 inches wide at the top, 17 inches long by 3½ inches wide at the bottom, and 4½ inches deep, with sloping sides 1 inch thick.

CONCENTRATES SMELTED.

The concentrates treated were practically subdivisions of grade No. 2, previously mentioned, and will be designated as No. 3 and No. 4. The coarser of the two grades, No. 3, is obtained by concentrating ore as follows: The rock is crushed with Blake breakers, stamped under a steam stamp; passed through a trommel with ¼-inch openings to a hydraulic classifier and to two jigs in series, the tailings from the last jig passing over a Wilfley table, the product of the table being grade No. 3. The overflow from the hydraulic classifier is conducted to a settling tank, and the slimes obtained are then treated upon a Card table, which gives grade No. 4. The copper in grade No. 3 was rather coarse and plainly visible; in No. 4 it was so fine that it could be detected only with difficulty by the naked eye, although by panning it was very easily concentrated to an appreciable extent. There was, however, considerable loss by sliming.

The sieve analyses of these concentrates are as follows:

Sieve analyses of Michigan copper concentrates.

Fineness.	No. 3.	No. 4.
	Per cent.	*Per cent.*
Less than 10-mesh	0.80	0.03
10 to 20 mesh	5.33	1.38
20 to 40 mesh	14.20	8.32
40 to 60 mesh	9.90	3.13
60 to 80 mesh	8.37	4.05
80 to 100 mesh	29.14	19.88
Over 100-mesh	32.22	63.19
	99.96	99.98

The great difference in the fineness of the two grades is apparent from these analyses, 87.12 per cent of No. 4 passing through a 60-mesh sieve, whereas only 69.73 per cent of No. 3 passed 60 mesh. The fineness of the material, especially that of the copper, seemed to affect the results obtained in the experiments.

The silica used was a ground quartzite containing 96.82 per cent SiO_2. The lime was from a limestone containing 63.2 per cent CaO and 5.7 per cent MgO. A hematite ore of the analysis given below was used as a flux.

The chemical analyses of the concentrates and of the hematite were as follows:

Chemical analyses of concentrates and hematite.

Constituent.	Concentrate No. 3.	Concentrate No. 4.	Hematite.
	Per cent.	*Per cent.*	*Per cent.*
Cu	37.35	25.35	
SiO_2	33.33	25.92	5.19
FeO	15.40	21.60	
Al_2O_3	8.78	12.40	1.22
CaO	5.18	5.98	0.20
MgO	1.09	1.09	0.16
S	0.056	0.096	
P			0.61
Fe	0.30	0.50	51.68
Mn			0.40

As may be seen from the above analyses, both grades of concentrates were rather high in alumina. The iron, silica, and alumina were so proportioned in each as to give a rather infusible slag. The concentrates were not uniform in composition, the analyses given being the average from several samples. This variation in composition of the concentrate affected the results in some experiments in that the calculated amount of copper in the charge and that tapped do not check well.

PROBLEMS OF ELECTRIC SMELTING OF NATIVE COPPER CONCENTRATES.

Before describing the experiments, some of the problems that arise in connection with the smelting of native copper concentrates in the electric furnace will be discussed.

As previously stated, the treatment of these concentrates consists of a melting operation and the separation of the metallic copper and gangue by reason of the difference in their specific gravities.

LOSS OF COPPER.

The loss of copper by slagging and volatilization depends upon the melting point, fluidity, and specific gravity of the slag. The slag should have as low a melting point and be as fluid as possible in order to prevent volatilization of the copper. In the electric furnace there is always a tendency for the furnace to develop a higher temperature as the melting point of the charge is raised, so that charges which could not be treated in an ordinary metallurgical furnace are easily smelted. For this reason the furnace must be watched to keep the temperature low in treating easily volatilized metals. As long as there is slag covering the metal in an electrode furnace the loss is not excessive, but with an arc and no slag the copper is rapidly volatilized or oxidized.

The loss of copper in the slag depends, as stated above, on the fluidity and specific gravity of the slag. The loss in treating native copper concentrates in the electric furnace is practically entirely due to mechanical loss of minute metallic globules that are carried off because of imperfect settling. A fluid and liquid slag of low specific gravity prevents such loss.

REDUCTION OF IRON OXIDE.

The only reducing material present in the electric furnace during a simple melting operation would be the carbon of the electrode. As a result, the reducing action need not be very strong in operating an electric furnace for this purpose. If the slag has a low melting point, there is no reason why the reduction of FeO to metallic iron should be excessive. This factor would have greater influence in a small furnace than in a large furnace, where the electrode area exposed to the charge would not be so great in proportion to the amount of material charged. In order to lower the reducing action, the temperature should be kept as low as possible and still give a fluid slag. Also in the electric furnace the effect of the base used to flux the silica may result in a decreased reduction of FeO.

DESCRIPTION OF EXPERIMENTS.

SMELTING CONCENTRATE NO. 4 WITHOUT FLUX.

Two experiments were made in which No. 4 concentrate was smelted without the addition of anything to flux the gangue, the results of which are shown in Table 2, experiments Nos. 1 and 2.

EXPERIMENT NO. 1.

Before experiment No. 1 was begun the furnace was heated with gas for an hour and a half to burn the tar out of the lining. The furnace was then filled with concentrate, and the current turned on.

Throughout the experiment the furnace did not run well and it was difficult to keep it from arcking at times. A green flame burned at the top, due to the oxidation of some of the copper. Carbon monoxide gas was also given off, due to the partial oxidation of the electrode.

In about one hour the charge was ready for tapping. Instead of tapping into an iron mold, as was done in later experiments, the charge was tapped into a mold made of bricks. The furnace did not tap well, because the bottom had settled, so that some metal was left in the furnace, and was later removed by chiseling.

No copper could be seen in the slag except at the bottom of the mold, where small pellets had concentrated. The slag flowed out of the furnace readily, but was a little thick, and had a glassy appearance when cold. Some of the carbon bottom came up and mixed with the slag in a semifused mass. There was not enough tar mixed with the carbon to make it set properly.

The metal contained so much iron that it could be seen with the naked eye. Under the microscope, iron, copper, and blowholes were visible, but no cuprous oxide.

EXPERIMENT NO. 2.

The furnace was hot when run No. 2 was started. The furnace tapped cleanly, the slag was glassy and rather thick, but flowed from the furnace. It was free from shots of metal. One brick in the furnace was eaten out by the slag. The metal showed the same characteristics as that from run No. 1.

VARYING THE ACIDITY OF THE SLAG WITH SILICA.

Five experiments were made, using varying amounts of silica for the purpose of noting the general effect of a very acid slag. Slags Nos. 3, 4, 5, 6, and 7 (see Table 2) were made in this manner. In all of these experiments No. 4 concentrate was used with silica as a flux.

EXPERIMENT NO. 3.

In experiment No. 3, the furnace was started cold. The furnace ran well, almost entirely as a resistance furnace. The green flame noted in the two previous experiments was present. The lining was in such poor condition that the metal could not be tapped, but was removed after cooling. The slag was viscous and very glassy, but flowed from the furnace. The metal showed iron and blowholes, but no cuprous oxide.

EXPERIMENT NO. 4.

In experiment No. 4, the furnace was hot from the previous run. The furnace ran well throughout the run, as a resistance furnace. The slag was viscous and very glassy, but flowed from the furnace. No iron or cuprous oxide were visible in the metal, but it contained some blowholes.

EXPERIMENT NO. 5.

Before beginning experiment No. 5 the furnace was relined and heated with the air to burn out the tar in the lining. The charge was slow in melting and shots of metal floated in the slag. On tapping, these seemed to settle toward the bottom of the mass. The slag was very thick and glassy, but flowed from the furnace. During the run, the furnace was operated entirely as a resistance furnace. The metal, on being tapped into two round ladles used for molds, froze and had to be melted out. This accounts for the abnormally high percentage of iron in the metal.

Under the microscope iron and blowholes were clearly visible, but no cuprous oxide.

EXPERIMENT NO. 6.

At the start of experiment No. 6 the furnace was cold. The power supply was very unsteady, being off for 18 minutes throughout the run. On tapping, the slag was thick and glassy, but flowed from the furnace, and no copper could be seen which did not settle out. There was a large amount of iron visible in the metal under the microscope, but it was present in a more dendritic form than in previous experiments. No cuprous oxide was formed.

EXPERIMENT NO. 7.

In experiment No. 7 the furnace was hot before charging. The slag was sticky and thick, but flowed from the furnace and was free from shots. Under the microscope very little iron could be seen in a section of the metal, and no cuprous oxide at all. The metal was also comparatively free from blowholes.

VARYING THE BASICITY OF SLAG WITH HEMATITE.

In experiments No. 8 and No. 9 (Table 2) hematite was used to note the effect of a more basic slag and the value of iron oxide as a flux in comparison with lime.

EXPERIMENT NO. 8.

In experiment No. 8 the furnace was hot before charging. The furnace acted better than in previous runs, probably because of the slag being more fusible. The slag was veiy fluid on tapping. It was of a dull basic appearance and free from shots of copper. Neither iron nor cuprous oxide was visible in the metal under the microscope.

EXPERIMENT NO. 9.

The furnace was cold at the beginning of experiment No. 9. The slag was dull, basic, and very fluid and was free from shots of metal. Neither iron nor cuprous oxide was visible in the metal.

VARYING THE BASICITY OF THE SLAG WITH LIMESTONE.

EXPERIMENT NO. 10.

In experiment No. 10 limestone was used as a flux. The furnace was hot at the start and operated well throughout the run. The slag was very fluid and basic and was free from shots of metal. A very little iron was visible under the microscope, but no cuprous oxide. The power consumption was very low.

VARYING THE BASICITY OF THE SLAG WITH LIMESTONE AND HEMATITE.

In experiments No. 11, No. 12, and No. 13 the basicity of the slag was changed by using both limestone and hematite and was increased as far as was considered practical.

EXPERIMENT NO. 11.

In experiment No. 11 the furnace was started cold. The slag was very fluid and boiled out of the top of the furnace considerably. Iron was distributed rather evenly throughout the metal as dendrites, but no cuprous oxide could be detected.

EXPERIMENT NO. 12.

The furnace was cold at the start of experiment No. 12. During the run fine globules of copper floated in the slag, which boiled out of the furnace considerably. There was so much of this boiling and slipping of the charge that some of the limestone dust was carried off by the gases. The slag was a little thick and sticky, but flowed readily from the furnace. Very fine dendrites of iron were visible in the metal, but there appeared to be no cuprous oxide.

EXPERIMENT NO. 13.

Experiment No. 13 was started with a hot furnace, but a rather sticky and thick slag was produced, which boiled and slipped so much that there was considerable loss of limestone and ore dust. There were shots of metal in the top of the slag in the furnace, but these settled out in the mold. Under the microscope only a few pieces of iron were visible in the metal and no cuprous oxide.

CONTINUOUS SMELTING.

EXPERIMENT NO. 14.

In experiment No. 14 concentrate No. 3, with lime as a flux, was charged at intervals so as to keep the furnace full, and three tappings were made during a run of 2 hours and 40 minutes. The furnace operated well and very little gas was given off, so long as the top of the charge was not fused.

When the bath was tapped, considerable material hung on the walls. The slags were very fluid, but the first two tapped contained considerable metal because of semifluid material running out of the furnace with the slag. No iron or cuprous oxide could be detected in the metal from any of the tappings.

RESULTS OF EXPERIMENTS.

The results of each experiment were tabulated as shown in Table 1, which gives the results of experiment No. 10 in detail.

TABLE 1.—*Results of smelting concentrate No. 3 with limestone flux, experiment No. 10.*

Time.	Amperes.	Volts.	Kilowatts.	Power factor.	Remarks.
P. m.					
12.35	500	70	33	94.3	Furnace started hot after experiment No. 9.
12.40	630	72	45	98.8	Charge all added at 12.37 p. m.
12.45	680	71	48	99.2	All fused at 12.46 p. m.
12.50	600	78	46	98.0	Shots of metal in upper part of slag.
12.55	580	80	46	99.0	Tapped. Slag fluid and free from shots.

Charge:	
Michigan concentrate No. 3, pounds	22.0
Limestone, pounds	2.2
Length of run, minutes	20
Mean volts in the furnace	74
Mean amperes on the furnace	598
Mean kilowatts on the furnace	44
Mean power factor of circuit	.97
Kilowatt-hours	14.4
Electrode consumption per pound of metal tapped, pounds	.052
Electrode consumption per ton of charge smelted, pounds	28.2
Calculated weight of copper, pounds	8.21
Weight of metal tapped, pounds	8.13
Weight of slag tapped, pounds	16.09
Loss of copper in the slag, per cent	.33
Copper unaccounted for, per cent	3.17
Total loss of copper, per cent	3.50
Kilowatt-hours per pound of metal tapped	1.77
Kilowatt-years per ton of ore smelted	.15
Kilowatt-years per ton of charge smelted	.135
Analysis of metal:	
Copper, per cent	97.13
Iron, per cent	2.50
Sulphur, per cent	.35
Arsenic, per cent	.02
Analysis of slag:	
Cu, per cent	.17
SiO_2, per cent	35.82
CaO, per cent	15.45
MgO, per cent	7.09
FeO, per cent	25.20
Al_2O_3, per cent	17.10

REMARKS.—On examining a microscopic section of the metal, after etching with picric acid, a few spots of dendritic iron could be seen, but no cuprous oxide.

The complete results of experiments 1 to 14 are tabulated in Table 2.

TABLE 2.—*Results of smelting of fine Michigan native copper concentrates in the electric furnace.*

Item.	Series 1.		Series 2.					Series 3.		Series 4.	Series 5.			Series 6.			Average.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14			
Composition of charge:																	
Concentrate No. 4, pounds	22.0	22.0	22.0	22.0	22.0	22.0	22.0	......	22.0	......	......	......	......		.....		......
Concentrate No. 3, pounds	......	......	......	......	......	......	......	22.0	......	22.0	19.6	19.6	22.0	5.5	97.1		......
Quartzite, pounds	......	......	2.2	2.2	4.4	4.4	4.4	......	......	......	......	......	......		.....		......
Hematite, pounds	......	......	......	......	......	......	......	1.1	2.2	......	1.98	4.18	6.6		.....		......
Limestone, pounds	......	......	......	......	......	......	......	......	......	2.2	1.98	4.18	6.6		9.71		......
Composition of metal:																	
Cu, per cent [a]	87.29	88.62	96.24	97.96	83.82	90.95	95.95	98.59	97.96	97.13	93.73	93.51	96.64	[b]99.49	[c]98.69	[d]97.77	......
Fe, per cent	12.50	11.10	3.50	1.75	15.90	9.25	3.75	1.10	1.90	2.50	6.20	6.30	3.10	[b].30	[c]1.04	[d]2.00	......
S, per cent	.19	.26	.24	.27	.26	.21	.30	.29	.12	.35	.15	.17	.24	[b].19	[c].25	[d].21	......
As, per cent	.02	.02	.02	.02	.02	.02	.02	.02	.03	.02	.02	.02	.02	[b].02	[c].02	[d].02	......
Composition of slag:																	
Cu, per cent	.40	.23	.31	.23	.15	.15	.10	.15	.02	.17	.54	.24	.46	[b]1.91	[c]1.60	[d].62	......
SiO_2, per cent	49.80	40.60	53.22	51.10	49.96	42.58	48.00	44.88	31.71	35.82	33.15	33.96	29.37	[b]34.01	[c]34.33	[d]34.62	......
CaO, per cent	13.25	9.07	12.40	8.78	10.10	8.80	9.00	6.92	10.10	15.45	17.60	20.04	19.20	[b]16.80	[c]17.50	[d]20.32	......
MgO, per cent	1.93	3.00	3.12	2.03	4.60	2.71	1.84	2.32	2.45	7.09	3.61	4.46	4.17	[b]2.95	[c]3.14	[d]2.86	......
FeO, per cent	15.25	21.15	11.58	25.50	19.90	29.00	26.25	29.80	37.95	25.20	29.00	27.60	31.25	[b]26.70	[c]27.30	[d]24.70	......
Al_2O_3, per cent	13.70	[e]23.82	20.33	10.45	16.10	16.48	14.99	15.34	14.89	17.10	16.28	11.75	14.10	[b]17.09	[c]14.83	[d]13.35	......
Length of run, minutes	50	30	30	24	25	23	22	23	23	20	25	30	26		100		......
Mean volts on the furnace	59	86	90	79	80	75	82	64	57	74	66	77	70		66		73
Mean amperes on the furnace	......	......	......	532	......	542	444	710	808	598	683	663	670		557		621
Mean kilowatts on the furnace	32	33	40	40	42	38	34	43	45	44	44	49	45		34		40
Mean power factor of circuit	......	......	......	.95	......	.95	.93	.94	.97	.97	.96	.97	.96		.94		.95
Kilowatt-hours	26.7	16.4	20	16	17 6	14.6	12.5	16.4	17.2	14.4	18.4	20.3	19.5		57.3		......
Electrode consumption per pound of metal tapped, pounds	.08	.16	.043	.12	.16	.12	.12	.052	.052	.052	.071	.071	.071		.036		.086
Electrode consumption per ton of charge smelted, pounds	48	41.9	21.8	33.25	41.9	33.25	33.25	28.20	28.20	28.20	34.20	34.20	34.20		22.10		34.5
Calculated weight of copper, pounds	5.58	5.58	5.58	5.58	5.58	5.58	5.58	8.21	5.58	8.21	7.31	7.31	8.20		36.30		......
Weight of metal tapped, pounds	[f]6.60	3.97	5.45	4.52	2.86	3.07	2.97	7.60	3.63	8.13	6.81	6.81	7.04	[b]11.0	[c]6.28	[g]15.28	......
Weight of slag tapped, pounds	13.58	21.10	16.22	21.30	17.95	15.82	22.20	14.42	16.40	16.09	16.20	16.60	15.03	[b]15.83	[c]16.55	[h]34.30	......
Loss of copper in slag, per cent	.97	.87	.90	.88	.48	.42	.40	.26	.59	.33	.54	.22	.85		2.12		.70
Copper unaccounted for, per cent	......	36.90	5.03	17.65	56.40	49.20	48.30	7.22	35.25	3.17	11.62	12.03	16.41		10.85		23.10
Total loss of copper, per cent	......	37.77	5.93	18.53	56.88	49.62	48.70	7.48	35.84	3.50	12.16	12.25	17.26		12.97		23.80
Kilowatt-hours per pound of metal tapped	4.05	4.13	3.67	3.53	6.30	4.75	4.19	2.13	4.73	1.77	2.68	2.96	2.77		1.76		3.51
Kilowatt-hours per ton of ore smelted	2,425	1,500	1,820	1,450	1,600	1,320	1,130	1,490	1,565	1,310	1,880	2,070	1,780		1,190		1,430
Kilowatt-hours per ton of charge	2,425	1,500	1,740	1,320	1,330	1,075	1,015	1,420	1,425	1,280	1,565	1,455	1,100		1,075		1,380

[a] Copper by difference.
[b] First tapping.
[c] Second tapping.
[d] Third tapping.
[e] Fire bricks melted into the slag.
[f] Copper left in furnace from previous run.
[g] Third tapping. Total metal tapped in all three tappings, 32.56 pounds.
[h] Third tapping. Total slag tapped in all three tappings, 66.80 pounds.

DISCUSSION OF RESULTS.

As previously stated, the three most important points for consideration are: (1) The loss of copper by slagging, volatilization, or by dust being carried off in the gases; (2) the reduction of the iron oxide to metallic iron which enters the copper; and (3) the power consumption and general operation of the furnace.

All of these factors are largely affected by the melting point of the slag and the temperature necessary to make it liquid enough to flow readily from the furnace. The results obtained from the experiments just described can be used as a basis for discussion in considering the commercial application of the electric furnace to the smelting of these concentrates.

COPPER LOSSES.

In order to have a uniform basis for comparing the results obtained by varying the silica, lime, and ferrous oxide contents of the slag, the oxygen ratios of the various slags were computed and tabulated. In doing this alumina was considered as a base. Of course the results, considered on this basis, do not show conclusively that a slag of a certain oxygen ratio gives the best results, because the high percentage of alumina in the slag varied considerably, owing to melting of the brick in the furnace lining. That is, the effect of alumina, when substituted for another base, on the fluidity of the slag is not shown completely.

The oxygen ratios of the different slags and the copper losses in the different tests were as follows:

Losses of copper with different slags.

Experiment No.	Ore smelted.	Flux used.	Oxygen ratio of slag. $\left(\frac{\text{Acid O}}{\text{Basic O}}\right)$	Proportion of copper in slag.	Proportion of copper lost.[a]		
					Losses in slag.	Losses by volatilization, in hanging pieces, and in dust.	Total.
				Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
4	Concentrate No. 4.	Silica	1.97	0.23	0.88	17.65	18.53
1	do	None	1.85	.40	.97	....	....
5	do	Silica	1.60	.15	.48	56.40	56.88
7	do	do	1.59	.10	.40	48.30	48.70
6	do	do	1.28	.15	.42	49.20	49.62
2	do	None	1.10	.23	.87	36.90	37.77
9	do	Hematite	.87	.20	.59	35.25	35.84
8	Concentrate No. 3.	do	1.44	.15	.26	7.22	7.48
12	do	Limestone and hematite	.93	.24	.22	12.03	12.25
10	do	Limestone	.91	.17	.33	3.17	3.50
13	do	Limestone and hematite	.82	.46	.85	16.41	17.26
11	do	do	.70	.54	.54	11.62	12.16

[a] Computed on basis of total copper in ore.

EXPERIMENTS WITH CONCENTRATE NO. 4.

From the table it is evident that as the acidity of the slag is decreased for concentrate No. 4 there is a gradual decrease in the percentage of copper in the slag until a slag having an oxygen ratio of 1.59 is reached, when the loss rises slightly and remains uniform with further increase of basicity. Concentrates No. 3 and No. 4 are considered separately because of the higher alumina and lower copper content in No. 4. The oxygen ratio does not vary directly with composition of the charge, because some of the slag from previous runs and some of the lining entered the slag. The ratio 1.59, at which the percentage of copper in the slag reaches the lowest point (0.10 per cent), corresponds to that of a slag containing 48 per cent SiO_2, 9 per cent CaO, 1.84 per cent MgO, 26.25 per cent FeO, and 14.99 per cent Al_2O_3. With this ratio the lowest percentage of losses in the slag from No. 4 concentrate, on the basis of total copper in the ore charged, occurred. The percentage of copper unaccounted for was high, however, though in all experiments, except where noted, the furnace was tapped practically clean, except for what slag stuck to the wall in spots. This unaccounted for loss may be considered as largely due to volatilization, dust loss, and hanging of the charge. To be on the safe side, all unaccounted for loss will be considered as volatilization and dust loss, although in a small furnace, without tearing out the lining, 10 per cent of hanging charge would not be excessive. The total loss of copper in experiment No. 7, including copper unaccounted for—that is, copper lost by volatilization, as dust, and by hanging of the charge, and the copper loss in the slag—was 48.7 per cent.

A further study of the results of lowering the acidity of the slag shows that although there is an increase in the percentage of copper in the slag it is not excessive, and that there is a considerable decrease in the percentage of copper lost in dust or by volatilization. With an oxygen ratio of 0.87, the percentage of copper in the slag is 0.20 per cent, the percentage of total copper charged that was lost in slag is 0.59 per cent, the copper unaccounted for is 35.25 per cent, and the total loss of copper 35.84 per cent. The slag resulting from experiment No. 4 shows the effect of a low percentage of alumina in a marked manner. This slag has an oxygen ratio of 1.97, greater than any of the others, but the loss by volatilization and in dust is less than in any other experiment with No. 4 concentrate, being 17.65. The slag contained 0.23 per cent copper, the total loss being 18.53 per cent of the copper contained in the quantity of ore charged. This slag contained 51.1 per cent SiO_2, 8.78 per cent CaO, 2.03 per cent MgO, 25.5 per cent FeO, and only 10.45 per cent of Al_2O_3. The cause of the decrease in the alumina content was not apparent. This evidently lowered the melting point considerably, so that less copper was volatilized.

The slag loss of copper was low in all of the experiments with No. 4 concentrate and the loss by volatilization and in dust was high. These two losses, the writers believe, can be eliminated. The material used was much finer than No. 3 concentrate, as shown by the analysis on p. 21. This fineness of subdivision accounts in a measure for the oxidization of copper dust, which was plainly visible during the experiments, as shown by the marked green flame. Also, more dust was carried off by the gases from the oxidation of the electrode than in the later experiments with concentrate No. 3. The results of the experiments with concentrate No. 3, in which a more basic slag was used, show that the volatilization loss can be kept low by using a slag with a low melting point. As the oxygen ratio was decreased in the tests with concentrate No. 4 the decrease of this loss was marked. The dust loss would be small in a large furnace. It probably would be necessary to use a slag higher in ferrous oxide and having a lower melting point for concentrate No. 4 than for No. 3, in order to keep down the oxidation and volatilization of fine copper.

EXPERIMENTS WITH CONCENTRATE NO. 3.

The experiments with concentrate No. 3 showed a much less total loss than did those with No. 4. This was undoubtedly due to the fact that the slags used for No. 3 had a lower oxygen ratio, resulting in a much more fluid slag with a lower melting point. Also bases were added to dilute the alumina, so that this constituent had less effect than in the previous experiments. The best results were obtained in experiment No. 10, in which the oxygen ratio of the slag was 0.91, the percentage of copper in the slag being 0.17. The total loss of copper in the slag was 0.33 per cent of the amount of copper in the ore charged. The loss by volatilization, in dust, and in hangings was 3.17 per cent, making a total loss of 3.5 per cent. These results were obtained by increasing the lime content by charging limestone, giving a slag containing 35.82 per cent SiO_2, 15.45 per cent CaO, 7.09 per cent MgO, 25.20 per cent FeO, and 17.10 per cent Al_2O_3. That this slag gives good results was confirmed in the continuous experiment No. 14, in which the same proportions of charge were used as was used in No. 10.

As the oxygen ratio became lower than about 0.91 there was a tendency for increased losses in the slag and a higher loss from other causes. It seems from the results that the most satisfactory slag for these particular ores is one with an oxygen ratio of about 1.0, that is, a monosilicate, and containing 35 per cent SiO_2, 22 per cent CaO and MgO, 25 per cent FeO, and 17 per cent Al_2O_3. The oxygen ratio of this slag corresponds to that of an ordinary copper blast furnace slag, but owing to the nature of the ore the alumina content is very high. Also the use of lime as a base instead of iron oxide seems to give better results with ore of high alumina and iron oxide content as regards copper losses, due probably to the formation of a slag of lower melting point. Increasing the lime content also lowers the specific gravity of the slag, thus permitting easier settling of the metal.

There is no reason why the results obtained with the coarser material No. 3 should not apply to the finer concentrate No. 4. The high losses in experiments with the latter were due largely to the high melting point of the slag. As no more ore was at hand, the experiments could not be continued with this concentrate, and No. 3 was used. The percentage of copper in the slag need not exceed 0.25 per cent with a slag of proper composition. The percentage loss in the slag of total copper in the ore charged should not exceed 0.5 per cent. The other losses in the best run (No. 10) amounted to 3.17 per cent, but in practice with continuous operation of a larger furnace this item should not exceed 1 per cent, and the total loss should not be over 1.5 per cent of the total amount of copper in the ore charged. The use of limestone is preferable in the case of the material treated, simply because of the production of a slag of easier fusibility and lower specific gravity, which allows better mechanical separation of metallic copper and slag and reduces the loss by volatilization. The dust loss would also be less if the very fine concentrate was mixed with a coarse concentrate.

IRON IN THE METALLIC COPPER.

In some of the runs in which a slag of high oxygen ratio and high melting point was used the percentage of iron in the copper produced was very high. The effect of length of run and of the ratio of acid to basic constituents in the slag is shown in the following table:

Metallic iron in the metal produced, experiments Nos. 1 to 13.

Experiment No.	Ore smelted.	Flux used.	Length of experiment.	Oxygen ratio. $\left(\frac{\text{Acid O}}{\text{Basic O}}\right)$	Proportion of iron in metal.	Weight of iron in metal.	Weight of metallic iron in charge.	Weight of iron reduced.	Percentage of electrode consumption used in reduction.
			Minutes.		*Per ct.*	*Pounds.*	*Pounds.*	*Pounds.*	
4	Concentrate No. 4.	Silica............	24	1.97	1.75	0.079	0.110	0.0	0.0
1	.....do......	None............	50	1.85	12.50	.825	.110	.715	29.10
3	.....do......	Silica............	30	1.68	3.50	.191	.110	.081	7.41
5	.....do......	.....do..........	25	1.60	15.90	.454	.110	.344	16.20
7	.....do......	.....do..........	22	1.50	3.75	.111	.110	.001	.06
6	.....do......	.....do..........	23	1.28	9.25	.283	.110	.173	10.35
2	.....do......	None............	30	1.10	11.10	.441	.110	.331	11.60
9	.....do......	Hematite........	23	.87	1.90	.069	.110	.0	.0
8	Concentrate No. 3.	.....do..........	23	1.44	1.10	.083	.066	.017	.92
12	.....do......	Limestone and hematite.	30	.93	6.30	.429	.059	.370	16.40
10	.....do......	Limestone.......	20	.91	2.50	.203	.066	.137	6.95
13	.....do......	Limestone and hematite.	26	.82	3.10	.217	.066	.151	6.50
11	.....do......	.....do..........	25	.70	6.20	.423	.059	.364	16.10

There was a small amount of free iron present in both concentrates No. 3 and No. 4, which entered the metal to an appreciable extent. This free iron was from the wear of breakers and stamps during milling of the ore. The influence exerted by the carbon electrode as a reducing agent is also shown in the table. Aside from iron little attention was paid in this research to other impurities in the copper, as it would be necessary to refine the copper in any case. The sulphur and arsenic ran about the same in all the samples. However, it was desirable to ascertain whether the ore could be melted and the gangue separated from the copper without reduction of iron by the carbon of the electrode to an extent that would contaminate the product and cause excessive expense in subsequent refining in a reverberatory furnace. In the reverberatory furnace the iron is removed from copper by oxidation and slagging, so that an excessive amount of iron, say over 5 per cent, would increase the cost of the process considerably.

FACTORS AFFECTING REDUCTION OF IRON BY THE ELECTRODE.

The chief factors which might have influenced the percentage of iron reduced by the carbon electrode are the length of time the ore was exposed to the electrode and the melting point of the slag formed. The time of exposure to the reducing action of the electrode did not appear to have a marked effect on the percentage of iron reduced, for in some tests a product high in iron was obtained after a run of the same length of time as an experiment in which the product contained little iron. For example, the copper from run No. 6, which lasted 23 minutes, contained 9.25 per cent of iron, whereas that from No. 9, which also lasted 23 minutes, contained only 1.90 per cent of iron.

A classification of the products of the experiments with both concentrates according to the oxygen ratios of the slags does not show a uniform change in the percentage of iron, but in general the percentage of iron reduced by the electrode decreases as the slag becomes more basic and approaches a monosilicate. This result is probably due entirely to the higher melting point of the more acid slag. The furnace, when operating as a resistance furnace, adjusts itself somewhat to the melting temperature of the charge so that with a refractory slag it gets hotter. This increase in temperature results in accelerating the reaction between the carbon electrode and the iron oxide of the gangue. With a monosilicate slag containing not over 15 per cent of alumina this reduction of iron need not result in a product containing over 2 per cent iron, including any metallic iron in the charge. This was shown by the results of the intermittent runs (see p. 28) and was further confirmed by experiment No. 14, in which the metals from three tappings during continuous operation of the furnace contained, respectively, 0.30 per cent, 1.04 per cent, and 2 per cent of iron.

The proportion of the total electrode consumption used in the reduction of iron varied from zero to 29.1 per cent, the average for 13 experiments being 9.35 per cent. From these results it may be seen that, with a furnace operating at a low temperature, the reduction of iron by the carbon electrode should not be excessive, or enough to result in a product containing less than 95 per cent of metallic copper. The writers believe that in practice the contents of metallic iron and other impurities could be kept as low as 2 per cent, giving a product containing 98 per cent copper.

EFFECT OF BASE USED.

The kind of base used to form a monosilicate slag did not seem to affect materially the reduction of iron oxide. The experiments indicate that there was slightly less reduction with hematite than when limestone was added, but there is so little difference that probably as good results could be obtained with one flux as with the other, the problem being simply one of economics as to which is the cheaper. The essential point is to have a fluid slag of low melting point, which can be obtained with either flux. It was thought in the beginning of the experiments that by the use of a slag high in silica it might be possible to eliminate the reducing effect of the electrode. This result was not accomplished in most of the tests because the slag formed was difficultly fusible, owing to the high alumina content of the ore. The high temperature increased the reducing effect so that any strong tendency of the FeO to combine with the SiO_2 was more than offset.

EFFECT OF ALUMINA.

Here, as well as in the discussion of copper losses, the effect of the alumina, as regards the reduction of iron oxide, should not be forgotten. In considering a series of very acid slags for copper losses and iron oxide reduction, it may be noticed that any diversion from high loss by volatilization was generally due to a decrease in the percentage of alumina in the slags. The adaptability of the electric furnace to smelting slags of high alumina content is clearly demonstrated by these experiments. As before stated, when the electric furnace is operated with the charge as the resistance and no arcs are formed, it adapts itself to the temperature required to melt the charge and produce a fluid slag. Of course there are many slags which could not be melted without undue power expenditure.

CONCLUSIONS.

These experiments show that the quantity of metallic iron reduced by the action of the carbon electrode is so small as to be of no practical mportance as a drawback to the substitution of the electric furnace for the reverberatory furnace in the smelting of these concentrates. The above statement also applies to sulphide copper ore. The small amount of iron which is reduced alloys with the copper, or, if the ore is a sulphide, enters the matte and increases its collecting power for gold, especially if the matte consists mainly of FeS. In either case not enough iron could be reduced to form a product so impure that excessive refining or reconcentration would be necessary.

POWER CONSUMPTION.

With the exception of the continuous run, experiment No. 14, the lowest power consumption and in general the best results of all the experiments were obtained in experiment No. 10, in which concentrate No. 3 was fluxed with limestone. For comparing the theoretical power consumption with the actual consumption the charge used in this run is taken as a basis.

For convenience, the results of this run will be reduced to the basis of 1,000 kilograms of ore; that is, 1 metric ton (2,204 pounds). The quantity of limestone required to flux 1,000 kilograms of ore is 220 kilograms. The metal is assumed to contain 2.50 per cent iron, which includes that reduced from the FeO of the ore by the carbon electrode, and any metallic iron present. The gases, CO from the electrode and CO_2 from the limestone, are assumed to escape at an average temperature of 500° C. at the top of the furnace during the melting stage. This temperature is high, but there was no shaft on the furnace. The ore is assumed to be dry and of the composition given on page 22. The loss of copper in the slag is assumed to be 0.33 per cent of the total amount of copper in the ore charged.

The results, computed on this basis, are as follows:

Results of smelting concentrate No. 3 with limestone flux on basis of 1,000 kilograms of ore, experiment No. 10.

	Quantity charged or consumed.	Quantity in product formed.		
		Metal.	Slag.	Gases.
Ore No. 3:	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*
Cu	373.5	372.27	1.23	
SiO_2	333.3		333.30	
Fe	122.7	9.53	113.17	
Al_2O_3	87.8		87.8	
CaO	51.8		51.8	
MgO	10.9		10.9	
O	34.3		32.5	1.8
	1,000.0			
Limestone flux:				
CaO	121.0		121.0	
MgO	19.09		19.09	
CO_2	79.2			79.2
Carbon of electrode	14.1			14.1
Oxygen from air, completely burned to CO, with oxygen from iron reduction	17.0			17.0
Total	1,264.69	381.80	770.79	112.1

Results of smelting concentrate No. 3 with limestone flux on basis of 1,000 kilograms of ore, experiment No. 10—Continued.

COMPOSITION OF SLAG.

Constituent.	Calculated.	Analyzed.
	Per cent.	*Per cent.*
Cu	0.16	0.17
SiO_2	43.20	35.82
CaO	22.40	15.45
MgO	3.88	7.09
FeO	18.81	25.20
Al_2O_3	11.37	17.10

The wide difference between the actual analysis and the calculated composition of the slag may be accounted for by several factors which must be taken into consideration. Possibly some of the fire-brick lining was fused and entered the charge, thus increasing the alumina content; or some of the previous charge, which contained hematite, may have been left in the furnace; also during the run considerable limestone was carried out of the furnace by the gases.

In the calculation of the theoretical power required it seems best to consider the melting point of the slag as that of the slag actually obtained. According to Hofman [a] the melting point of a slag containing 32.1 per cent SiO_2, 17.95 per cent FeO, 16 per cent CaO, and 11.37 per cent Al_2O_3 is 1,310° C. and that of a slag containing 32.1 per cent SiO_2, 24.69 per cent FeO, 22 per cent CaO, and 11.37 per cent Al_2O_3 is 1,145° C. The melting point of the slag actually obtained in run No. 10 is assumed to be 1,250° C. and the temperature necessary to make it flow to be 1,350° C. The quantity of heat necessary to melt and superheat the slag is assumed to be 600 calories per kilogram. In oxidizing C to CO, 8,100 calories are developed per kilogram of carbon. The amount of heat necessary to reduce 1 kilogram of Fe from FeO is assumed to be 1,173 calories. The quantity of heat necessary to expel 1 kilogram of CO_2 from $CaCO_3$ is 191 calories. The specific heat of dry carbon monoxide at 0° to 500° C. is 0.256 calorie per kilogram and that of carbon dioxide is 0.245 calorie per kilogram. It is assumed that 204 calories of heat are required to melt and superheat 1 kilogram of pure copper, and that 370 calories are required for 1 kilogram of iron. The metal contained some iron, but owing to insufficient data on the specific heats of alloys of iron and copper, the specific heat of pure copper is used. All of the heat constants are taken from Richards's "Metallurgical Calculations."

The theoretical amount of heat required to smelt 1,000 kg. of ore may now be computed, as follows:

---

[a] Peters, E. D., Principles of copper smelting, 1907, p. 395.

Theoretical amount of heat required to smelt 1,000 kg. of ore.

	Calories.
Melting and superheating 372.27 kg. of copper.....372.27×204=	75,943
Melting and superheating 9.53 kg. of iron............9.53×370=	3,386
Reducing 9.53 kg. of Fe from FeO.................9.53×1,170=	11,178
Melting and superheating 770.79 kg. of slag........770.79×600=	462,474
Raising the temperature of 32.8 kg. of CO to 500° C.......... ....500×0.256×32.8=	4,195
Raising the temperature of 79.2 kg. of CO_2 to 500° C.......... ....500×0.245×79.2=	9,650
Total..	566,826
Amount of heat supplied by combustion of 14.1 kg. of carbon ....14.1×8,100=	114,210
Amount of heat supplied by electric current..................	452,616
Total..	566,826

The theoretical amount of electrical energy required for smelting No. 3 concentrate is $\frac{452,616}{857}=529$ kilowatt-hours per metric ton of concentrate charged, or 481 kilowatt-hours per short ton, or 0.055 kilowatt-year per ton. On the basis of total charge the energy consumption is 393 kilowatt-hours per short ton of charge or 0.045 kilowatt-year per ton. The theoretical energy consumption per pound of copper produced is 0.63 kilowatt-hour.

In experiment No. 10 the actual power consumption was 1,310 kilowatt-hours per ton of ore smelted, 1,280 kilowatt-hours per ton of charge smelted, and 1.77 kilowatt-hours per pound of metal tapped. As 1,310 kilowatt-hours per ton of ore smelted were actually used, whereas 481 kilowatt-hours per short ton are theoretically required, without allowing for heat losses or other inefficiency, the furnace used 2.72 times more power than was theoretically necessary, or it had a heat efficiency of 36.76 per cent.

The power consumption in experiments 1 to 13, tabulated according to the oxygen ratios of the slags, is as follows:

Power consumption in smelting tests of native copper concentrates.

Experiment No.	Ore used.	Flux.	Oxygen ratio. $\left(\frac{\text{Acid O}}{\text{Basic O}}\right)$	Power consumption—		
				Per pound of metal tapped.	Per ton of ore smelted.	Per ton of charge smelted.
				Kw.-hours.	*Kw.-hours.*	*Kw.-hours.*
4	Concentrate No. 4.	Silica	1.97	3.53	1,450	1,320
1	.....do	None	1.85	4.05	2,425	2,425
3	.....do	Silica	1.68	3.67	1,820	1,740
5	.....do	.....do	1.60	6.30	1,600	1,330
7	.....do	.....do	1.59	4.19	1,130	1,015
6	.....do	.....do	1.28	4.75	1,320	1,075
2	.....do	None	1.10	4.13	1,500	1,500
9	.....do	Hematite	.87	4.73	1,565	1,425
8	Concentrate No. 3.	.....do	1.44	2.13	1,490	1,420
12	.....do	Limestone and hematite	.93	2.06	2,070	1,455
10	.....do	Limestone	.91	1.77	1,310	1,280
13	.....do	Limestone and hematite	.82	2.77	1,780	1,100
11	.....do	.....do	.70	2.68	1,880	1,565

As some of the charges were treated longer than was absolutely necessary, the power consumption varied and the results are not uniform. The power consumption per pound of metal tapped in some of the runs with No. 4 concentrate was high, owing to the low amount of metal tapped, but of course was less when concentrate No. 3, which contained a higher percentage of copper, was charged. A low power consumption per ton of charge was obtained with No. 4 ore in experiments 6 and 7, in which slags with oxygen ratios of 1.28 and 1.59, respectively, were produced, but the volatilization loss was so high as to prohibit the use of such charges. The lowest power consumption obtained in any of the experiments in which copper losses were not excessive was in runs 10 and 13, being 1,280 and 1,100 kilowatt-hours per ton of charge. Limestone flux was used for No. 10 and a mixture of limestone and hematite for No. 13, the oxygen ratios of the slags being 0.91 and 0.82, respectively.

In general it may be stated that the most satisfactory results, as regards both power consumption and copper losses, are obtained when the native copper concentrate is fluxed with limestone or hematite, or both, in such proportions that the slag formed approximates a monosilicate. With the small furnace used, which required 40 kilowatts—the average in 14 experiments—a heat efficiency of 36.76 per cent was obtained. A 750-kilowatt commercial furnace of modern design, equipped with feeding shafts and a covered top, when working on similar ore should have a heat efficiency of 70 per cent and possibly higher, as the process consists of simply melting the ore, but 70 per cent may be taken as a safe figure. In experiment No. 14, in which the furnace was run continuously on the same kind of charge as was used in No. 10, the power consumption was even lower than in No. 10, because of the continuous charging, being 1.76 kilowatt-hours per pound of metal, 1,190 kilowatt-hours per ton of ore, and 1,075 kilowatt-hours per ton of charge.

On the basis of 70 per cent efficiency a large 750-kilowatt furnace would consume only $\frac{36.76}{70} \times 100 = 52.5$ per cent as much energy as the small 40-kilowatt furnace in smelting the same amount of ore. Hence it may be stated that the following power-consumption figures should be obtained in smelting fine Michigan native copper concentrates, containing from 25 to 40 per cent copper, in a 750-kilowatt commercial electric furnace: Kilowatt-hours per pound of metal tapped, $0.525 \times 1.76 = 0.92$; kilowatt-hour per ton of ore smelted, $0.525 \times 1{,}190 = 625$; kilowatt-hours per ton of charge smelted, $0.525 \times 1{,}075 = 564$.

OPERATION OF FURNACE.

No difficulty was experienced in operating the furnace on the resistance principle. The fineness of the material assisted in this considerably, as there was not so great a tendency for arcking with the particles of the charge packed closely. After the first few experiments it was found that the furnace worked best at 70 volts, and the voltage was kept at about 70 during later runs. The average power on the furnace was 40 kilowatts at a voltage of 73 volts and an amperage of 621 amperes. The power factor was high, averaging 0.95. As the furnace was over powered little difficulty was experienced in starting it. The fire-brick walls were not corroded appreciably by the charge, but when superheating was prolonged after the charge had been melted the fire brick melted in some places and mixed with the slag. This accounts for the variable nature of the slag as compared with that of the materials charged. The carbon bottom used in the first three experiments was not properly put in and was replaced by another rammed in harder, which lasted throughout the experiments, and was apparently not at all affected. Ground coke mixed with tar to a paste gives as good satisfaction as ground graphite electrode butts.

ELECTRODE CONSUMPTION.

The average electrode consumption throughout all of the experiments was 34.5 pounds of graphitized carbon per short ton of charge. The highest consumption, 48 pounds, was in experiment No. 1 and the lowest, 22.1 pounds, was in experiment No. 14. This last figure more nearly represents practical working conditions and could undoubtedly be attained, and even bettered, in practice. The atmosphere of the electric furnace is practically neutral during the melting of a material in which all of the iron oxide (FeO) is combined to form a silicate. For this reason the consumption of the electrode, although it would not be as low as in a reducing atmosphere, should not be excessive, because of the combined state of the ferrous oxide. In practice the electrode consumption should not exceed 10 pounds per ton of charge and probably would be much less.

From these results it is evident that the loss of electrodes through contact with the charge would not form a serious objection to the substitution of the electric furnace for the reverberatory furnace in smelting copper ores. If all of the electrode consumption were used in the reduction of oxides, the amount of energy consumed in supplying heat for reactions might be appreciable, but as an average of only 9.35 per cent of the total electrode loss was so used any loss of electrical energy in this way may be considered as negligible.

UTILIZATION OF SLAGS FOR PRODUCTION OF FERROSILICON.

In connection with the electric smelting of both oxide and sulphide ores of copper, the idea has always been prevalent that it is possible to utilize the slag for making ferrosilicon in the electric furnace, but not much actual experimental work has been done to determine the feasibility of the process.

To obtain information on the factors involved a series of experiments was undertaken.

Five experiments were made, using two lots of slag produced in smelting the native copper concentrates. The composition of these slags, as shown by analysis, was as follows:

Analyses of slags used.

Constituent.	No. 1.	No. 2.
	Per cent.	*Per cent.*
CuO	0.22	0.80
SiO_2	46.19	34.63
CaO	9.61	16.54
MgO	2.55	3.57
FeO	24.10	28.24
Al_2O_3	16.58	14.75

The coke that was used contained 84.38 per cent of fixed carbon, 0.34 per cent of moisture, 0.61 per cent of volatile and combustible matter, and 14.67 per cent of ash. The iron ore and silica were of the composition given on pages 21 and 22. The results of the tests are negative, but are given to show that the making of ferrosilicon from copper slags, which has been assumed by some writers to be possible without experimental confirmation, is a difficult matter.

EXPERIMENT WITH SLAG AND COKE.

In the first experiment, No. 15, 61.6 pounds of slag No. 1 and 17.6 pounds of coke were charged. There was some copper frozen in the furnace when it was charged, which partly accounts for the high percentage of copper in the product. An attempt was made to operate the furnace continuously, but both the metal and the slag were too thick to flow from the furnace, although several attempts were made to tap it during the run. At the end of the run 8.3 pounds of metal were tapped, but the slag would not flow. The slag was removed as far as possible by balling with iron rods, and what could not be removed in this way was chiseled out when cold. The total amount of slag obtained was 59.3 pounds. The metal was very brittle, looked like white iron, and had the appearance of ferrosilicon containing 25 per cent of silicon. Dense white fumes were given off during the run. The power consumption was 3.82 kilowatt-years per ton of metal tapped, or about 10 times the power required to produce 1 ton of "25 per cent" ferrosilicon from iron turnings, quartz, and coal in a commercial ferrosilicon furnace. Coke was charged in amount sufficient to reduce all iron and silicon charged. Possibly, however, some silicon carbide was formed, as this compound tends to form if an excess of coke be present. The effect of silicon carbide is to make the slag thick. The amount of copper in the metal was considerably greater than the amount charged, for the reason previously stated.

The product contained 21.23 per cent silicon, 58.01 per cent iron, 19.35 per cent copper, 0.02 per cent phosphorus, and a trace of sulphur. The slag contained 46.25 per cent SiO_2, 22.4 per cent Al_2O_3, 14.6 per cent FeO, 9.81 per cent CaO, and 2.70 per cent MgO.

EXPERIMENT WITH SLAG, QUARTZ, AND COKE.

In experiment No. 16 the charge consisted of 44 pounds of slag No. 2, 14.65 pounds of quartz, and 12.24 pounds of coke. The charge was calculated to give a product containing 50 per cent of silicon and a slag containing 40 per cent of SiO_2, on the assumption that all of the coke was used for the reduction. The results were similar to those obtained in the previous run; the slag fused, but would not flow from the furnace, the yield of metal was low, and the power consumption was high. The ferrosilicon contained 18.38 per cent silicon, 73.02 per cent iron, 7.01 per cent copper, 0.08 per cent sulphur, and 0.04 per cent phosphorus. The slag contained 49.63 per cent SiO_2, 27.24 per cent Al_2O_3, 9.76 per cent FeO, 9.85 per cent CaO, and 2.60 per cent MgO.

OTHER EXPERIMENTS.

Three other experiments were conducted in which even more negative results were obtained. In one, iron ore was added to ascertain whether the presence of iron in an easily reducible form would accelerate the silicate reduction, just as it lowers the reduction temperature of silica not combined as silicate, but no beneficial effect was obtained. In these runs part of the slag would flow from the furnace, but the product was a high-silicon pig iron. Fine grinding was tried, but it caused the material to pack so that the furnace could not be made to arc steadily, and the maintenance of a steady arc is necessary to attain a high enough temperature for the production of ferrosilicon.

DISCUSSION OF RESULTS.

In these particular experiments the production of ferrosilicon from slag in the electric furnace must be accounted a failure because of the low yield of ferrosilicon, due to the difficulty of reducing the silicate and to the tendency of the constituents of the slag other than iron and silica to rob the ferrosilicon of those elements. As a result of this, the power consumption and the difficulty of operating the furnace were too great for practical purposes. The remarks on the results of these experiments apply in general to the production of ferrosilicon from slags. The writers believe that it would be impractical to attempt the manufacture of ferrosilicon from a slag containing more than 10 per cent of oxide other than FeO or SiO_2 because of the clogging up of the furnace with the difficultly fusible slag resulting. With even 10 per cent of oxide present to form a slag with the FeO and SiO_2, it would probably not be possible to make a ferrosilicon containing over 30 per cent silicon. In the commercial production of ferrosilicon from iron turnings and silica in the electric furnace, "30 per cent" ferrosilicon can be made if some slag is present; a "50 per cent" product can be made only with difficulty, and higher grades not at all, if any slag is formed.

Even if the proper slag is available, the process, except under unusual circumstances, does not seem commercially attractive. A copper smelter is usually situated in a district remote from steel centers, where the greatest market for ferrosilicon is found. The slag, in order to compete with iron turnings, or iron ore, and quartz or sand as raw material for making ferrosilicon, must be cheap enough to offset the disadvantages of being possibly farther from the market, and requiring a higher power consumption.

CONCLUSIONS.

The conclusions that were drawn from the experiments described in the preceding pages are as follows:

1. Fine Michigan native copper concentrates can be smelted in the electric furnace with the production of a good grade of black copper and without excessive losses of copper in the slag or by other means.

2. The percentage of copper in slag of the proper composition need not be more than 0.25 per cent. The proportion of total copper charged that is lost in slag should not exceed 0.5 per cent, and all other losses should not exceed 1 per cent, or the total loss should be not more than 1.5 per cent.

3. The loss of copper by volatilization is high if the slag is much more acid than a monosilicate or if it contains much alumina. The lowest losses were obtained when limestone was added to form a slag containing 35 per cent of SiO_2, 22 per cent of CaO and MgO, and 25 per cent of FeO.

4. The difference between limestone and hematite as a flux is not marked, one being about as efficient for this purpose as the other if the slag is not of too high a specific gravity. No more iron was found in the black copper product when hematite was used than when limestone was used.

5. With a furnace operating at a low temperature on a monosilicate slag, the reduction of iron by the carbon electrode should not be excessive or sufficient to result in a product containing less than 95 per cent of metallic copper. With care a product containing 98 per cent of copper could probably be produced regularly.

6. The total electrode consumption greatly exceeded the amount of carbon necessary for reduction of the iron found in the metal, as an average of only 9.35 per cent of the total amount of electrode consumed was used in iron reduction. In practice the electrode consumption should not exceed 10 pounds per ton of charge.

7. The electric furnace operates satisfactorily with the highly siliceous-aluminous slag produced by the natural gangue without flux, but the losses by volatilization are high because of the high melting point of the slag. There was no copper oxide in the product, as was shown by microscopic examinations.

8. The power consumption for smelting fine Michigan native copper concentrates, carrying 25 to 40 per cent of copper, in an electric furnace of 750 kilowatts or greater capacity should not exceed 625 kilowatt-hours per ton of ore smelted.

9. The production of ferrosilicon from the copper slags can not be economically accomplished if the slag contains large proportions of components other than ferrous oxide and silica.

PROPOSED PROCESS FOR ELECTRIC SMELTING OF FINE NATIVE COPPER CONCENTRATE.

The commercial smelting of fine native copper concentrate in the electric furnace, in order to attain the greatest economy, would be a continuous operation. The process would consist of charging the mixture of ore and flux at intervals into the top of an electric furnace having a short stack above the smelting crucible for preheating the charge before it reached the smelting zone, and tapping the metal at intervals, the slag being permitted to run continuously from the furnace through a slag notch above the metal hole.

The possibility of operating a furnace in this manner was shown in experiment No. 14. There was an average of 1.10 per cent of iron in the product, and 1.37 per cent of copper in the slag. The total loss of copper was as low as in the intermittent runs and was largely due to the small scale of the operation. The loss of copper in the slag was high because of imperfect settling and because of the tapping of partly fluid material with the slags, a condition that would not occur in a large furnace properly operated. The power consumption was lower than in the other experiments.

DESCRIPTION OF FURNACE.

The furnace features essential to the success of this process are a crucible, in which the electrical energy is introduced, and in which the metal settles from the slag, and a short shaft above the crucible for preheating the charge before it reaches the smelting zone. As there is no reduction to be performed in the shaft it need not be higher than to give plenty of space between the top of the crucible and the charging floor for head room in moving the electrodes.

A furnace of the type shown in figures 3 and 4 satisfies these conditions. The furnace has a smelting chamber, *a*, lined with fire brick or silica brick; three carbon electrodes, *b*, suspended vertically through the roof; and a feeding shaft, *c*, which is lined with fire brick, over the crucible.

A 750-kilowatt furnace of this type would smelt in 24 hours about 23 tons of native copper concentrates, carrying 25 to 40 per cent copper. This furnace would be operated with three-phase current at from 50 to 100 volts. The internal dimensions of a 750-kilowatt furnace of this type are as follows: The crucible is 14 feet 6 inches in diameter and 9 feet high, the shaft is 1 foot 6 inches in diameter and 18 feet 6 inches high.

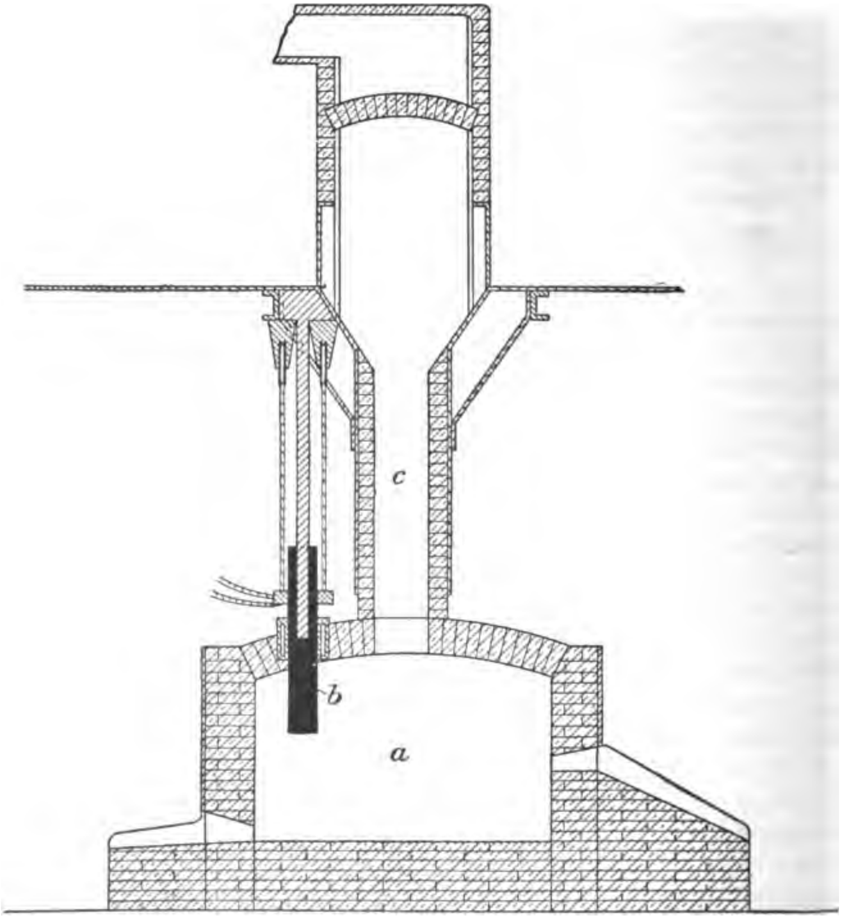


FIGURE 3.—Elevation of electric furnace for smelting native copper concentrates.

As regulation of electrodes would not be necessary in this type of furnace when in regular operation the electrical connections are made close to the roof of the furnace, and regulation is by hand. There is less difficulty in handling the electrodes if they are suspended vertically, and the vertical shaft eliminates the need of suspending the electrodes at an angle of about 55 degrees.

The slag from such a furnace should not contain more than 0.25 per cent copper, and could be discarded at once without further treatment.

It could be granulated with water as discharged from the furnace. The metal would require further refining for elimination of iron and other impurities, and could be charged directly from the electric furnace into a reverberatory furnace and refined as previously described.

COMPARISON OF PROPOSED AND PRESENT METHODS.

The present method of treating these concentrates consists of the following steps:

1. The coarse concentrate is melted and refined in either one or two reverberatory furnaces, from which a slag is produced containing from 10 to 30 per cent copper.

2. The fine concentrate is agglomerated in a reverberatory furnace, or briquetted with lime.

3. The slags from the reverberatory furnace and the agglomerated, or briquetted, fine material is smelted with coke in a blast furnace. The slags from the blast furnace contain 0.6 to 0.8 per cent copper and the metal 90 to 95 per cent copper.

4. The metal from the blast furnace is re-treated in a reverberatory furnace.

There would be the following advantages in using the electric furnace for smelting these concentrates: (1) No agglomeration or briquetting would be necessary; (2) none of the slags produced would require re-treatment; (3) a large proportion of the higher grade concentrates, containing 75 per cent copper, could be mixed with the fine concentrates and treated directly in the electric furnace, thus reducing the amount of slag necessary for resmelting; and (4) if cheap power were available the electric furnace could be used for reducing the copper from the reverberatory slags. The resulting metal would probably be lower in iron, and the slag lower in copper because of the greater ease of regulating the reducing atmosphere in the electric furnace, as the amount of coke is sufficient only for the reduction of the combined copper.

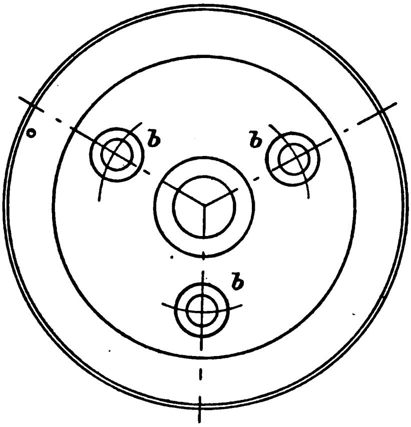


FIGURE 4.—Plan of electric furnace for smelting native copper concentrates.

The limit to the amount of higher grade concentrates that could be mixed with the fine material would be determined by the electrical conductivity of the mixture in the furnace. In the experiments performed, no short circuits or other difficulties were experienced in smelting a charge containing 37 per cent metallic copper. The point to which the proportion of copper in the charge could be increased would have to be ascertained by experiment.

Technically, the electric furnace does away with the necessity of briquetting or nodulizing the fine concentrates and in general facilitates handling of the materials. The commercial factors influencing the choice of the method to be adopted, as regards cost, would largely depend upon local cost of power and fuel. As regards present practice, the cost of fuel, the cost of briquetting or nodulizing, and possibly a higher labor cost are to be set against the cost of power for electric smelting. Even if the cost of power were equal to these three factors, the electric furnace might still have the advantage because of ease of operation.

In the case of a mine remote from smelting plants it might be cheaper to concentrate by smelting in a small electric furnace the low-grade product obtained by wet concentration and thus reduce the cost of freight. Also to save losses in wet concentration the ore might not be so highly concentrated by wet methods, a low-grade concentrate being made which could be smelted directly in the electric furnace, the high-grade black copper made being shipped to a custom smelter.

COST OF ELECTRIC SMELTING COMPARED WITH COST OF PRESENT METHODS.

Some reliable figures have been obtained by the bureau regarding the cost of smelting fine native copper concentrates in Michigan. These concentrates, containing 35 per cent copper, are agglomerated in a reverberatory furnace. One ton of concentrate yields 0.21 ton of metallic copper and 0.79 ton of slag containing 18 per cent copper. The slag is resmelted in a blast furnace and the copper is refined in a reverberatory and made into marketable shapes. On resmelting in the blast furnace, 0.79 ton of slag yields 0.152 ton of cupola block containing 88.9 per cent copper. The blast furnace slag averages 0.6 to 0.8 per cent copper. These blocks are refined in a reverberatory furnace, the yield from 0.152 ton being 0.129 ton of copper and 0.023 ton of slag. The copper is made into marketable forms and the slag is re-treated in the blast furnace.

Thus in treating one ton of concentrates a total of 0.813 ton of slag must be re-treated in the blast furnace.

The cost of smelting concentrates by the above method is given in the table following. The cost figures include overhead charges, all repairs, and maintenance of plant, but not amortization of investment.

Cost of smelting 1 ton of "35 per cent" native copper concentrate by reverberatory process.

	Per ton of concentrate.
Smelting 1 ton of concentrate in reverberatory furnace	$3.69
Making marketable shapes from 0.21 ton of copper, at $1.96 per ton	.41
Resmelting 0.79 ton of slag in blast furnace, at $4.71 per ton	3.72
Refining 0.152 ton of "cupola block" in reverberatory, at $2.77 per ton	.42
Making marketable shapes from 0.129 ton of copper, at $1.96 per ton	.25
Treatment of 0.023 ton of slag in blast furnace, about	.15
Total	8.64

For estimating the cost of treatment of these concentrates by the combined electric and reverberatory process, the electric furnace is assumed to be a 750-kilowatt furnace with a capacity of 28 tons per 24 hours. The cost of the plant, including cost of buildings, transformers, and furnace, is estimated at $20,000, which is a liberal estimate, as the furnace alone, including transformers, can be erected for $10,000. Reverberatory furnace smelting costs are taken as given in the preceding table. The furnace is assumed to be operating at a smelter where only a portion of the total superintendence, laboratory, and general costs would be charged against it.

The cost per ton of concentrate with power costs of 0.50, 0.625, 0.75, and 1 cent per kilowatt-hour is estimated to be as follows:

Estimated cost of smelting one ton of "35 per cent" native copper concentrate by the combined electric and reverberatory method.

Item.	Cost per ton of concentrate at a power cost per kilowatt-hour of—			
	0.5 cent.	0.625 cent.	0.75 cent.	1 cent.
Smelting in the electric furnace:				
Limestone, 0.10 ton at $1 per ton	$0.10	$0.10	$0.10	$0.10
Electrodes, 1 pound, at 4 cents per pound	.44	.44	.44	.44
Power, 640 kilowatt-hours	3.20	4.00	4.80	6.40
Labor, 3 men at $2 each and a boy at $1 per 8-hour shift	.75	.75	.75	.75
Superintendence, chemist, general expenses	.20	.20	.20	.20
Maintenance and repairs	.25	.25	.25	.25
Amortization and depreciation on $20,000 at 5 per cent each	.18	.18	.18	.18
Interest, on $20,000 at 6 per cent	.11	.11	.11	.11
Total	5.23	6.03	6.83	8.43
Smelting in the reverberatory furnace:				
Reverberatory refining of 0.352 ton of "cupola block"[a], at $2.77 per ton	.97	.97	.97	.97
Retreatment of 0.05 ton of slag from reverberatory	.25	.25	.25	.25
Cost of making marketable copper of 0.345 ton copper at $1.96 per ton	.67	.67	.67	.67
Total	1.89	1.89	1.89	1.89
Total cost of smelting ore per ton of concentrate	7.12	7.92	8.71	10.32

[a] Cupola blocks 98 per cent copper. Total loss of copper 1.5 per cent.

According to these figures the electric process with power at 0.5 cent per kilowatt-hour or $43.80 per kilowatt-year is $1.52 per ton cheaper, at 0.625 cent per kilowatt-hour is $0.72 per ton cheaper, and at 0.75 cent is $0.07 more expensive than the reverberatory process. The commercial operation of such a process does not require power of the great cheapness necessary in iron smelting to compete with existing processes. A rate of 0.5 cent per kilowatt-hour with a high load factor is possible in many districts. The load factor in this case would be above 90 per cent and the power factor not below 0.85. In practice the cost of refining the "cupola block" of the electric furnace would probably be considerably reduced over that of the blast furnace because of the higher percentage of copper in it.

Also by the electric process there would be only 0.023 tons of slag per ton of concentrate to be resmelted instead of 0.813 tons as with the present process.

SMELTING OF SULPHIDE COPPER ORES.

ORDINARY COPPER BLAST-FURNACE SMELTING.

Ordinary copper blast-furnace smelting—that is, smelting the ore with carbonaceous fuel—differs widely from pyritic smelting, which consists in smelting the ore with heat derived by the oxidation of the sulphur and iron contained in the ore itself.

As stated by Peters,[a] "The main characteristic of ordinary blast-furnace smelting is the employment of carbonaceous fuel mixed with ore as the principle source of heat." Such being the case, the problem that presents itself is to determine whether it is metallurgically feasible to substitute electricity for carbonaceous fuel as a source of heat and whether in so doing there will be obtained as favorable results chemically as it is possible to obtain in ordinary blast-furnace smelting.

PRINCIPAL FEATURES OF THE PROCESS.

The prerequisites and distinguishing features of ordinary copper blast-furnace smelting, as stated by Peters,[b] are as follows:

(*a*) The employment of moderately compressed air to effect combustion.

(*b*) The complete, or nearly complete, continuity of the smelting process, due to the fact that the ore and fuel are fed periodically on top of the charge column at the upper extremity of the furnace shaft and withdrawn continuously (or periodically) in a molten state from the lower portion of the furnace, so that the operation of blast-furnace smelting, as understood by copper metallurgists, is not only continuous but, theoretically speaking, perpetual.

(*c*) The actual contact of the ore and fuel, these substances being charged into the top of the furnace in alternate layers.

(*d*) The employment of carbonized or high-carbon fuel, such as coke, anthracite, or charcoal, to avoid the annoyance and danger arising from the presence in the ore column of the volatile hydrocarbons and various products of distillation which would result from the use of wood or the ordinary coals containing volatile matter.

---

[a] Peters, E. D., Principles of copper smelting, 1907.

[b] Peters, E. D., Op. cit., pp. 109, 167.

In ordinary blast-furnace smelting the atmosphere is distinctly reducing, owing to the presence of large quantities of C and CO, which have a greater affinity for O than have most of the constituents of the charge. Under normal conditions, however, this reducing action is not sufficiently powerful to reduce the oxides of iron to metallic iron, although it reduces Fe_2O_3 and Fe_3O_4 to FeO, providing there is SiO_2 present to combine with this base at the instant of its formation.

In the true pyrite blast furnace, however, where very little coke is used, the atmosphere may be regarded as neutral until the focus is reached. Here we first encounter the O of the blast, and the atmosphere is powerfully oxidizing, * * * but as the O has a greater affinity for the iron sulphide than it has for any other important substance that should ever reach the focus, and as there is—or should be—always more iron sulphide present than there is O to burn it, it follows that even the atmosphere of the focus of the pyrite furnace may be regarded as neutral toward a certain proportion of the iron sulphide, as well as toward various other substances that may come within its influence.

REMOVAL OF SULPHUR.

In the smelting of copper ores, sulphide ores in the main have to be dealt with and the problem consists in getting rid of the sulphides other than copper, and of concentrating the latter into a matte containing anywhere from 20 to 60 per cent copper. The first step, therefore, is to free the ore from its sulphur. Consider first how this is done in ordinary copper blast-furnace smelting. As pointed out by Peters,[a] owing to the constant presence of a large amount of glowing carbon in the furnace shaft, extending from the tuyères for several feet up the shaft of the furnace and often to the charging door itself, the oxygen of the air blown through the tuyères is consumed with extraordinary rapidity and thoroughness, and there is consequently but a poor chance for the oxidation of any substance in the ore that possesses less affinity for oxygen than carbon does.

Therefore, in ordinary blast-furnace smelting with carbonaceous fuel, the sulphides of iron and copper, and such small quantities of other metallic sulphides as may be present, stand little chance of obtaining any of the oxygen to combine with, to form sulphur dioxide and metal oxide. The atmosphere is almost always strongly reducing, and the sulphides tend to melt down with almost the same results that they would in a closed crucible, with complete exclusion of air.

It will thus be seen that, owing to the reducing atmosphere which prevails, we can, when smelting sulphide ores, look for the removal of but little sulphur in the blast furnace beyond the portion that will be driven off by heat alone without the presence of oxygen.

Of the two sulphides in the charge which have to be taken into consideration in this connection, namely, pyrite (FeS_2) and chalcopyrite ($Cu_2S.Fe_2S_3$), the former loses one-half of its sulphur content by mere heating without air, whereas the latter, when similarly heated, loses one-third of its sulphur content and one-ninth of its entire weight.

---

[a] Peters, E. D., Principles of copper smelting, 1907, p. 109.

Continuing, Peters states:

> It is obvious, then, that there would be little object in smelting unroasted ores carrying a high percentage of metallic sulphides in a blast furnace running on carbonaceous fuel.

From what has been stated, it would appear that electric heat could be used as well for the melting down of the ore as heat derived from the combustion of coke.

However, such melting would not, in either case, give the concentration desired. The concentration of the copper and accompanying precious metals into a matte must be by the removal of sulphur and the subsequent oxidation of the iron.

The removal of sulphur in ordinary blast-furnace smelting is brought about in two ways, namely, by heat alone, which drives off a part of the sulphur as elemental sulphur, and from the reaction of oxides and sulphates, present in the ore as such, on the sulphides. The presence of oxides in the charge may be due to the use of natural oxide ores, whereas if roasted ores are used, both oxides and sulphates may be present. These components react with the sulphides present, a partial oxidation of the latter takes place, and some of the sulphur is removed as sulphur dioxide (SO_2). It is to be remembered that the atmosphere of the ordinary blast furnace is reducing, and therefore in this instance these reactions have to take place in a reducing atmosphere, and for this reason do not take place as freely as they would in a neutral atmosphere. In general it may be stated that with no oxides present in the charge practically no sulphur (aside from that removed as elemental sulphur by heat, as above stated) would be driven off except, as stated by Peters,[a] "the small amount that would be oxidized by the blast, in spite of the generally reducing atmosphere of the furnace." He also states that, judging from his own experience, this "loss of extra sulphur in the blast furnace can not be placed higher than 5 per cent of the sulphur remaining in the ore after deducting the sulphur which the pyrite and chalcopyrite lose by direct volatilization."

POSSIBILITY OF SUBSTITUTING THE ELECTRIC FURNACE.

Ordinary blast-furnace smelting of copper ores consists simply of melting down the ore, and the sulphur removed is that which is removed when a sulphide is heated without air. Any concentration that takes place is due to the reactions which take place between the oxides and sulphates present, and which would take place better in a neutral atmosphere than they do in a blast furnace, the atmosphere of which is reducing. Such being the case, a blast furnace operating in this manner is only a melting-down furnace, and the same results would be obtained by melting such an ore in an open crucible. The only advantage which the blast furnace has over the reverberatory furnace in this instance is that it is more efficient as a melting furnace than is the reverberatory, because it affords intimate contact between the fuel of the charge and the resultant gases and permits of continuous smelting. On the other hand the reactions between the oxides and sulphates do not take place as readily as they would in the comparatively neutral atmosphere of the reverberatory furnace, or in the still more neutral atmosphere of the electric furnace. So far, then, aside from the question of costs, there is apparently no reason why the electric furnace could not be substituted for the ordinary blast furnace in smelting the class of ores above mentioned.

---

[a] Peters, E. D., Principles of copper smelting, 1907, p. 116.

LOSSES OF METALS.

According to Peters,[a] the losses which occur in ordinary blast-furnace work are (1) the loss of dust, which contains valuable metals, every time the ore is moved; (2) losses of dust in the flue gases, owing to the blast; (3) volatilization losses; and (4) losses in slag "due to particles of matte or metal which have failed to separate properly from the slag and, to a lesser degree, from the oxidation of the oxides of the valuable metals, especially lead and copper, that have entered into combination with the silica and have thus become chemically part of the slag."

The relative extent to which these losses would occur if an electric furnace (with no blast) were used instead of a blast furnace operated in the manner previously described will now be discussed.

Loss of dust in handling the ore would be common, of course, both to the blast furnace and the electric furnace.

Although there would be more or less fine dust carried away by the gases escaping from the electric furnace, the amount, of course, would not be as great as with the blast furnace.

As regards loss by volatilization, an electric furnace, used for smelting sulphide ore, would be operated as a resistance furnace (the charge acting as the resistor) rather than as an arc furnace, and hence the heat in the vicinity of the electrodes would not be as intense as if an arc were used, and probably not greatly in excess of that which is generated at the tuyères of such a blast furnace as has been considered.

If an electric blast furnace of the type shown in figures 5 and 6 be used, the volatilization would take place at the base of the shaft of the furnace, and hence the volatilized metals would have a chance to be deposited out on the cold part of the charge in the upper part of the stack, and as it would not be necessary to use a blast when operating

---

[a] Peters, E. D., Principles of copper smelting, 1907, p. 113.

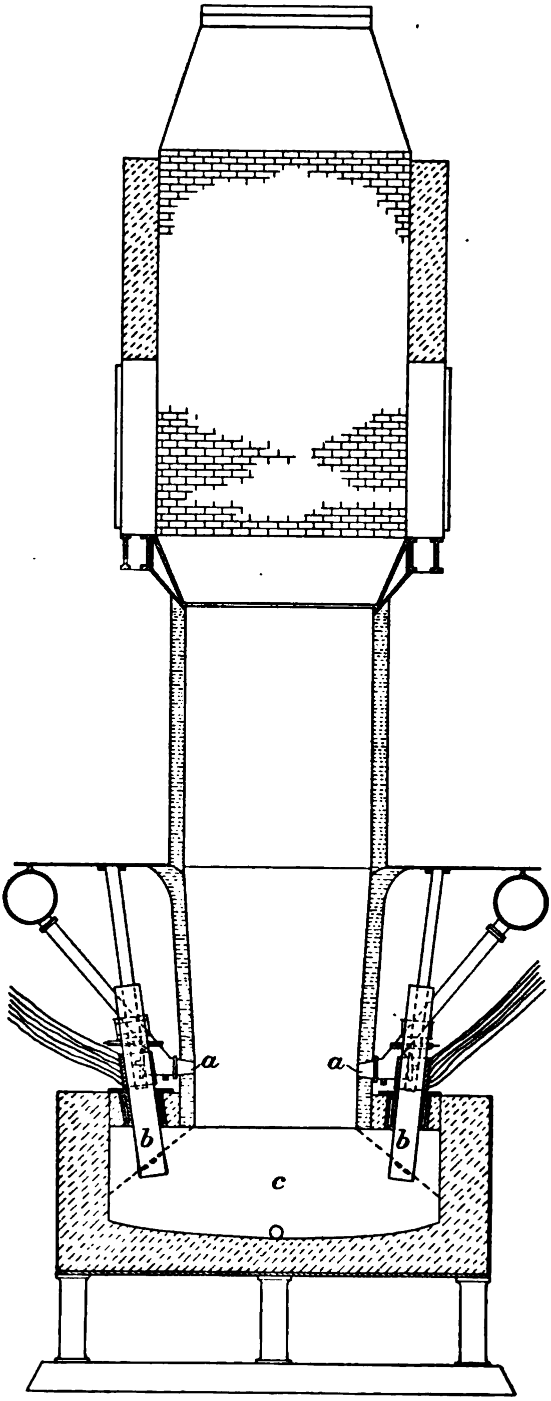
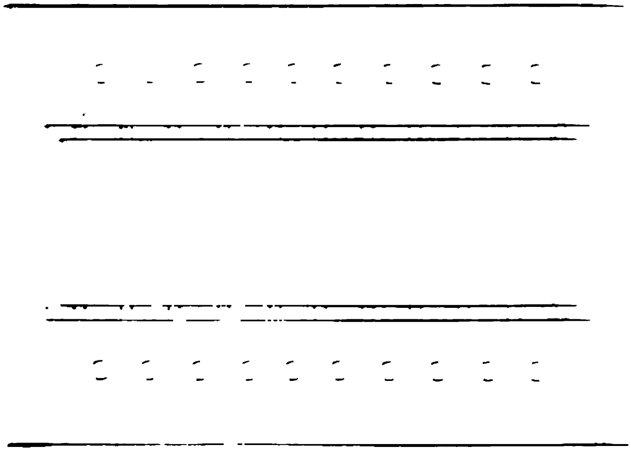


FIGURE 5.—Elevation of electric blast furnace. *a*, tuyères; *b*, electrodes; *c*, crucible.

the electric furnace for the purposes under discussion—[illegible] blast furnace in this particular instance is used [illegible] air for burning the coke to produce the heat necessary [illegible]—the volatilization loss should be [illegible] and probably would be [illegible] as in the blast furnace.

As regards the losses in the slag owing to particles of matte metal failing to separate properly from the slag, such losses would occur in the electric furnace as well as in the blast furnace, but there is no reason to believe that they would be any greater [illegible] other hand, they should not be as large, because the electric furnace could be regulated to impart a sufficiently high temperature to the bath before it leaves the furnace to insure its being fluid enough to cause perfect separation of matte and slag in the settler, which would thus obviate the loss [illegible] the ordinary [illegible] valuable metals. The



[illegible] electrode

loss should be [illegible] a minimum [illegible] furnace operating without a blast [illegible] loss [illegible] the action of the blast upon the [illegible] as they pass the region of the tuyeres.

DATA ON EXPERIMENTAL SMELTING OF RAW SULPHIDE, OXIDIZED AND CARBONATE ORES

Having thus made a brief comparative study of the possibility of using an electric furnace for the smelting of [illegible] ores—it being understood, of course, that the object of the paper is not to prove that the electric furnace should replace the combustion furnace, but to ascertain, if possible, whether it could be substituted for the combustion furnace in those localities which are favorable to its use—[illegible] some of the experimental work which has been done along this line [illegible] above mentioned.

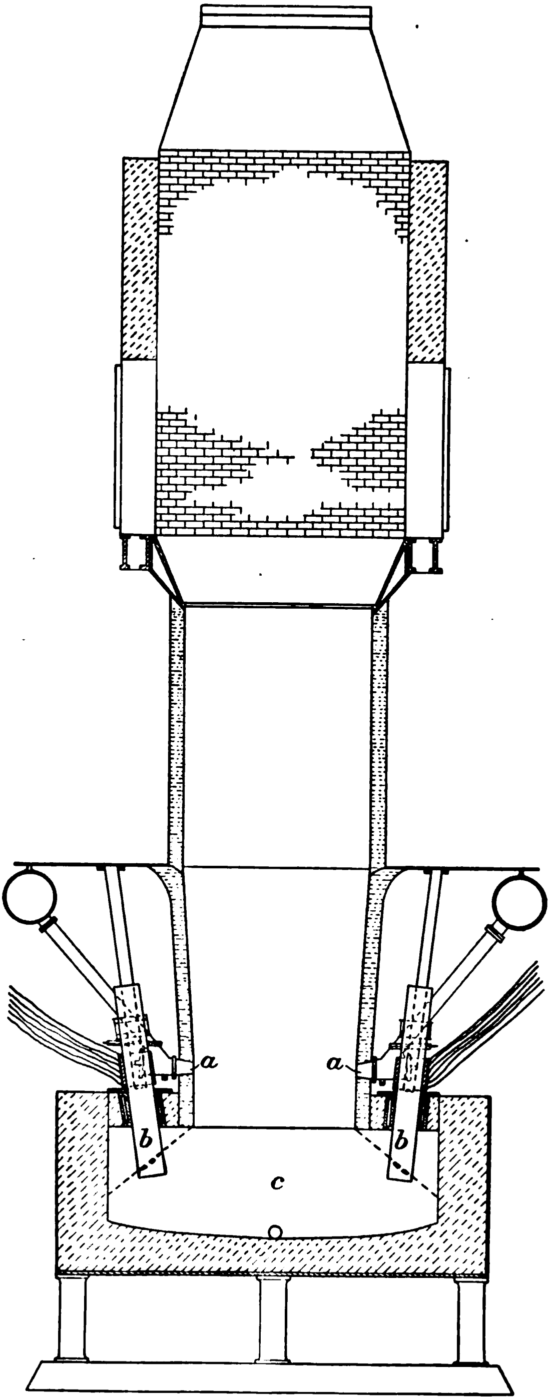


FIGURE 5.—Elevation of electric blast furnace. *a*, tuyères; *b*, electrodes; *c*, crucible.

the electric furnace for the purpose under discussion—the blast of the blast furnace in this particular instance is used only for furnishing air for burning the coke to produce the heat necessary for the process—the volatilization loss should not, and probably would not, be as great as in the blast furnace.

As regards the losses in the slag owing to particles of matte or metal failing to separate properly from the slag, such losses would occur in the electric furnace as well as in the blast furnace, but there is no reason to believe that they would be any greater and on the other hand they should not be as large, because the electric furnace could be regulated to impart a sufficiently high temperature to the bath before it leaves the furnace to insure its being fluid enough to cause perfect separation of matte and slag in the settler, which would thus obviate this loss. As to the oxidation of valuable metals, this loss should be reduced to a minimum in a furnace operating without a blast, for the loss by oxidation is doubtless due to the action of the blast upon the products of the furnace as they pass the region of the tuyères.

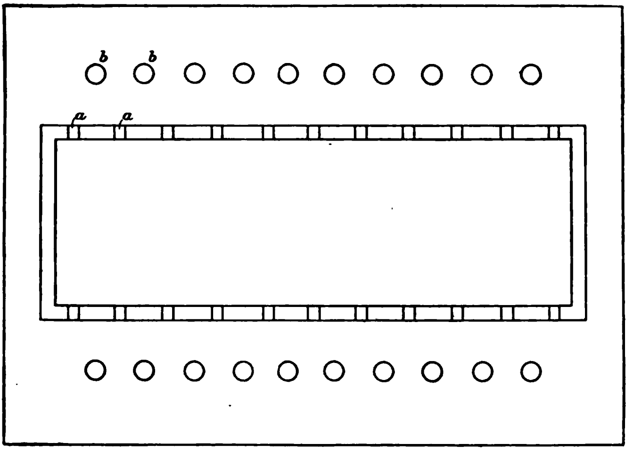


FIGURE 6.—Plan of electric blast furnace. *a*, tuyères; *b*, electrodes.

DATA ON EXPERIMENTAL SMELTING OF RAW SULPHIDE, OXIDIZED, AND CARBONATE ORES.

Having thus made a brief comparative study of the possibility of using an electric furnace for the smelting of mixed sulphide and oxide ores—it being understood, of course, that the object of this paper is not to prove that the electric furnace should replace the combustion furnace, but to determine, if possible, whether it can be substituted for the combustion furnace in those localities which are not favorable to the latter—it may be well at this point to consider some of the experimental work which has been done along the lines above indicated.

EXPERIMENT BY VATTIER.

One of the best known experiments on the smelting of copper ores in the electric furnace was made on April 23, 1903, by Vattier[a] at the works of the Compagnie Electrothermique Keller et Leleux, at Livet, France. The test was made by Vattier for the Chilean Government, which wished to procure such data as it would be possible to obtain in making experiments on a commercial scale. The test was made before a commission which was composed of some of the best known metallurgists of England and continental Europe.

As stated by Vattier, the main object of the experiment was to determine, if possible, whether in smelting copper electric heat could be substituted either wholly or in part for the heat derived from coal. This is especially important to Chile, for it has plenty of valuable copper ores, so it is stated, and an abundance of water power, but coal is costly.

METHOD AND RESULTS OF TEST.

The experiment was conducted with two kinds of ore, namely—

(1) An ore carrying approximately 7 per cent of copper which was present principally as copper pyrites, 8 to 9 per cent of sulphur, the gangue consisting mainly of micaceous copper oxide, together with some silicates and a little carbonate of lime; and

(2) A low-grade copper ore from the mining regions in the vicinity of Santiago, Chile, mixed with a small proportion of manganese and lime.

In the experiment a shaft furnace was used which had a smelting chamber 70 inches long, 35 inches wide, and 35 inches high. The melted material was run into a forehearth 47 inches long and 23 inches high. Two carbon electrodes, 11¾ inches square by 66 inches long, were used in the smelting chamber, and two electrodes 9¾ inches square by 39 inches long were put in the forehearth to reheat the bath for tapping.

The furnace used, so Vattier states, "Had a capacity of 25 tons of ore per 24 hours. The current used for the experiments was 4,750 amperes, 119 volts, cosine ϕ equals 0.9, and the energy corresponded to 500 kilowatts, or 680 horsepower."

The charge used was a mixture of the two ores. About 8,000 kilograms of ore was smelted in eight hours. The composition of the charge was as follows:

---

[a] Haanel, E., Report of the commission appointed to investigate the different electrothermic processes for the smelting of iron ores and the making of steel in operation in Europe, Mines Branch, Department of the Interior, Canada, 1909, pp. 215–223.

Composition of charge.

	Per cent.
Carbonic acid	4.310
Silica	23.700
Alumina	4.0
Lime	7.300
Magnesia	0.33
Sulphur	4.125
Iron	28.500
Manganese	7.640
Phosphorus	0.046
Copper	5.100
Arsenic	Trace.

Matte and slag of the following composition were obtained:

Analysis of matte and slag.

Constituent.	Composition of matte.	Composition of slag.
	Per ct.	*Per ct.*
Silica	0.80	27.20
Alumina	.50	5.20
Lime	....	9.90
Iron	24.30	32.50
Manganese	1.40	8.23
Sulphur	22.96	.57
Phosphorus	.005	.06
Copper	47.90	.10

DISCUSSION OF RESULTS.

Vattier remarks that the slags at both the beginning and end of the run usually contained a slightly higher proportion of copper. He does not say why this was so, or whether the copper present was free or combined. Uncombined copper would probably be present in larger amounts at the beginning of the run, because of the viscosity of the slag, due to lack of heat, preventing proper settling; also a slightly higher proportion of copper at the end of the run would probably be due to the same cause—that is, improper settling.

Vattier also states that the slag, being high in iron and silica, could be used to manufacture ferrosilicon, but, as has been previously pointed out in this bulletin, the results of experiments by the Bureau of Mines indicate that such utilization of slag is impractical.

Vattier also states that, "For good results it is desirable to use a voltage sufficient to cause the arc or electric current * * * to just clear the surface of the bath, in order to avoid as much as possible their (the electrodes) coming in contact with the bath."

His reason for wishing to keep the electrodes out of contact with the bath is explained by his statement that "Carbon at such high temperature has a tendency to reduce the iron oxide into metallic iron, which gives rise to the following inconveniences: (1) A more rapid wear of electrodes; (2) loss of electrical energy; and (3) decrease of the copper contents of the matte."

It is of course true that, if the electrodes extend down into the charge, as they do when the furnace is operated as a resistance furnace (the charge acting as the resistor) instead of an arc furnace, any iron oxide coming in contact with the carbon of the electrodes will be reduced by the carbon and thus cause a wearing away of the electrodes. On the other hand, in tests which have been conducted by members of the bureau and others, it has been found that more satisfactory results are obtained if the charge be smelted by resistance heating, using the charge as the resistor, than if it be smelted by heat from an arc. With the arc a very high local temperature is obtained and hence volatilization losses are higher than if resistance heating, which heats the charge more uniformly, is employed. The loss of electrical energy and the production of a low-grade matte resulting from the reduction of metallic iron has been previously discussed under experiments by the writers.

EXPERIMENTS BY SCHILOWSKI.

SMELTING MIXTURES OF RAW AND ROASTED ORE.

More recently some experiments were conducted by J. Schilowski [a] for the purpose of determining whether it would be possible to obtain in one operation a reaction between raw ore and roasted ore that would give a usable copper and a clean slag, Schilowski states that in these experiments he used a furnace which "had an upper carbon electrode and a water-cooled lower electrode," but he does not give much information in regard to the furnace beyond this. It was probably a small furnace, holding, perhaps, 25 pounds of ore, of the Siemens vertical type, shown in figures 1 and 2.

Analyses of the raw and roasted ore used in the tests are as follows:

Analyses of raw and roasted ore used in experiment.

	Raw ore.	Roasted ore.
	Per cent.	*Per cent.*
SiO_2	20.30	22.5
Cu	10.10	10.5
Fe	27.10	34.6
Al_2O_3	9.45	11.5
As	9.25	Trace.
Mn	.48	.5
S	15.09	1.5
Bi	Trace.	....
Co		....
Au		....
Ag	([b])	....

---

[a] Schilowski, J., La fusion electriques des minerais de cuivre et des produits intermediares de fonderies de cuivre: Revue Met., vol. 9, 1912, p. 205.

[b] 0.116 ounces per ton.

The amount of copper unaccounted for was very large in most of the tests, especially when only roasted ore was used. The unexplained losses are probably due to volatilization and mechanical losses, especially the latter, for the gases arising from a small electric furnace carry with them a large amount of fine particles.

A second group of experiments was made to determine what proportions of raw ore should be used in the charge in order to obtain the largest percentage of copper in the matte with the minimum difficulty of fusion.

Schilowski states that in the experiments he used "two electrodes of carbon projecting into the slag." From this the authors judge that the fusion was done much the same as it would be if a charge were fused in a single-phase Héroult steel furnace.

DISCUSSION OF RESULTS.

As a result of his experiments, Schilowski states that the proportion of raw ore that should be used in making up a charge depends on the consumption of energy and the loss of copper in the slag.

He obtained these conditions with a charge containing 60 to 70 per cent of roasted ore. With such a charge, the loss of copper in the slag was 5 per cent of the total copper present in the charge, and the weight of the copper in the speiss was one-ninth of the weight of the copper in the matte.

He also found that the maximum energy consumption was when the charge was made up entirely of crude ore, and the minimum energy consumption was when the charge contained 64 per cent of roasted ore. He states that in treating a mixture of ores of this nature that 17,400 kilowatt-hours would be required per ton of copper produced.

He also states that the high losses of copper were due to the violence of the furnace reaction. The writers have not noticed that the reactions were especially violent in any of the experiments of this nature which they have performed. It is true that after the charge becomes melted it bubbles or boils considerably, due to the gases which are being given off, and it is also true that, in order to get a satisfactory separation of matte and slag, the fused product must be kept at a melting temperature for some little time, just as is done in a settler in commercial smelting. That this is not always done in experimental work may account for some of the high losses of copper in the slag.

RECOVERY OF ARSENIC FROM RAW ORE.

Another experiment was made by Schilowski in order to determine whether a recovery of arsenic could be made by fusing the raw ore.

METHOD OF TEST.

The fusion was made in a carbon crucible with a bottom carbon electrode. A carbon resistance of carbon block was placed in the crucible between the electrodes. A covering was placed around the crucible in order to prevent loss of heat by radiation. The gases were led off through a tube and then through several condensing chambers.

RESULTS OF TEST.

No speiss was obtained in this experiment. The matte contained 21.37 per cent of copper, 50.27 per cent of iron, and 28.39 per cent of sulphur. The slag contained only 0.15 per cent copper. In treating a quantity of ore corresponding to a ton of copper 27,500 kilowatt-hours were used per ton of copper produced.

An analysis of the fine material obtained as a result of the volatilization was as follows:

Composition of volatilized material.	Per cent.
As	60
Fe	2
Cu	1
S	7
Miscellaneous	16

Schilowski states that in spite of the imperfections of the condensing apparatus, 65 per cent of the arsenic was recovered, and that it would be feasible to attempt the recovery of arsenic from the raw ore in this manner.

EXPERIMENTS BY WOLKOFF.

Wolkoff [a] made some experiments on the smelting of a copper sulphide ore, containing 8.20 per cent of copper, with an acid gangue. Several experimental runs were made with this ore. The results from one or two of them will be briefly discussed.

SMELTING ORE AND IRON OXIDE TO OBTAIN MATTE.

In one experiment, by smelting 12 kilograms (25.5 pounds) of ore, with 6.2 per cent of hammer scale (iron oxide) added to furnish iron oxide for the siliceous gangue, he obtained a thoroughly fused product, a matte containing practically the whole of the copper, and a slag retaining only 0.15 per cent of the copper. He also states that the volatilization losses were very small.

SMELTING ORE AND MATTE TO OBTAIN METALLIC COPPER.

In another experiment he smelted 10 kilograms (22 pounds) of ore with 1.25 kilograms (2.74 pounds) of roasted matte, containing 75 per cent CuO, 8 per cent Cu_2S, and 15 per cent Fe_2O_3, the object being to determine the extent to which the reaction $Cu_2S + 2\ CuO = 2\ Cu_2 + SO_2$, resulting in the production of metallic copper, would take place. On smelting this charge with a current of 400 amperes at 75 volts for half an hour, Wolkoff obtained 1.78 kilograms (3.91 pounds) of metal which was 92 per cent copper, 3 per cent iron, and 1 per cent sulphur. He also obtained 10.9 kilograms (2.39 pounds) of slag with a copper content of 0.10 per cent. In this experiment 96 per cent of the copper was extracted; the slag contained 0.6 per cent of the total quantity of copper; therefore, as stated by Wolkoff, the copper balance is as follows:

---

[a] Wolkoff, W., Electric smelting of copper sulphide ore: Metallurgie, vol. 7, 1910, p. 99.

	Kilograms of copper.
1.78 kilograms of crude copper (92 per cent copper)	1.638
10.9 kilograms of slag with 0.1 per cent copper	0.111
Losses	0.057
Total copper in charge	1.706

EXPERIMENTS BY STEPHAN.

At the first general meeting of the recently formed society of German Metallurgical Engineers, M. Stephan, superintendent of the Girod electric steel works, at Ugine, France, gave an account of some experiments made by him on the electric smelting of nonferrous ores, one of which was a copper ore. The following is an abstract of Stephan's paper:[a]

SMELTING NONFERROUS ORE IN THE ELECTRIC FURNACE.

The ore came from the Belgian Congo, being mined by a Belgian-English concern. In five different analyses given the CuO varies from 21.01 to 5.73 per cent; SiO_2 from 28.48 to 78.55 per cent; Al_2O_3 from 4 to 13 per cent; Fe_2O_3 from 4 to 16 per cent; and, besides smaller amounts of other impurities,'2 to 7 per cent CoO, and no nickel.

The moisture in the ore varied from 7 to 32 per cent. It was not removed, in order to meet the conditions of practical operation and to carry the experiments out under most unfavorable conditions.

Charcoal, coke, and anthracite were used successfully as reducing agents. Charcoal would probably be the cheapest in this particular instance.

Electric furnaces similar to the Girod ferro-alloy furnace were used, and the dimensions changed in several runs within wide limits in order to secure enough data for the construction of a large furnace for the same work. Electrodes were suspended from the top and inserted in the bottom, also in the sides for heating by radiation, and a system was adopted of heating with a smothered arc, mainly by the resistance of a thick layer of slag over the conducting metallic charge. The temperatures were measured with Le Chatelier and Fèry pyrometers.

A slag of the composition 51.9 per cent SiO_2, 11.31 per cent Al_2O_3, 16.83 per cent CaO, 13.71 per cent MgO, 3.55 per cent Fe_2O_3, 0.94 per cent MnO, 0.46 per cent CuO, and 0.87 CoO begins to melt at 1,250° C. and is liquid enough at 1,400° C. to allow the little copper balls to settle completely. At 1,550° C. the slag is liquid enough to flow freely; 1,920° C. were necessary to render the slag liquid when the highly acid charge was smelted without any fluxes.

The pig copper (Schwarzkupfer) produced in six different runs analyzed from 65 to 95 per cent copper, from 1 to 21 per cent iron, and from 1 to 11 per cent cobalt. The lower the smelting temperature the higher will be the purity of the product.

The lower the temperature the smaller will be the chance for reducing any of its impurities, but at the same time more copper will also be retained in the slag, so that the output is decreased.

---

[a] Stephan, M. Einiges über die Erzeugung von Metallen im elektrischen Ofen: Metall und Erz, vol. 1, 1913, p. 11; abstracted in Met. and Chem. Eng., vol. 11, 1913, p. 22.

CONCLUSIONS OF STEPHAN.

Stephan's conclusions as to the results of the experiments were as follows:

It will be a matter of commercial calculation, according to the composition of the ore and other special conditions, whether a high quality product or a maximum output will be desirable.

A continuous run for several days with the same ore, aiming at slags of about the above-mentioned composition, required 1,000 to 1,200 kilowatt-hours per ton (2,205 pounds) of ore. These figures are high as a result of the amount of heat required to keep the very viscous and abnormal slags in liquid condition.

With an easily fluxible ore the power consumption was only 500 kilowatt-hours per ton.

The electrode consumption averaged 8 kilograms, or 17.6 pounds per ton of ore. It (the electrode) was operated with 4 amperes per square centimeter (25.8 amperes per square inch).

Coal for reduction was used at the rate of 25 per cent of the copper in the charge.

The best lining to withstand the severe conditions of the furnace was tamped from fire clay with 80 per cent SiO_2 and 15 per cent Al_2O_3.

EXPERIMENTAL SMELTING OF SULPHIDE ORES IN THE ELECTRIC FURNACE.

A series of experiments on the smelting of sulphide ores in the electric furnace was recently conducted at the Bureau of Mines laboratory by the writers. The objects in view were: (1) To determine if there are any conditions arising which make electric smelting without air anything but a simple melting operation; (2) to note the percentage of concentration and the sulphur removal; (3) to study the possibility of condensation of the elemental sulphur as such; (4) to get general figures on power consumption with varying charges; (5) to determine losses of gold, silver, and copper, and (6) to study the use of a low-grade copper matte as a collecting agent for gold and silver.

ORES TREATED.

The ores used in the experiments were a low-grade sulphide copper ore high in sulphur, a gold and silver bearing siliceous ore, and some roasted ore; the analyses of the ores are given below. Limestone containing 63.2 per cent CaO and 5.7 per cent MgO was used to flux the ore.

Analyses of ores used in electric smelting of sulphides.

Constituent.	Raw pyritic ore.	Nodule.	Siliceous ore.
	Per cent.	*Per cent.*	*Per cent.*
SiO_2	2.50	4.00	74.53
Fe	44.07	65.60	10.71
S	48.20	....	8.36
Al_2O_3	.24	1.76	.40
CaO	.08	.45	....
MgO	.73	.46	.26
P	.02	....	....
As	.20	....	....
Cu	1.30	.07	....
	Ounce per ton.	*Ounce per ton.*	*Ounces per ton.*
u	0.01	0.03	1.28
g	.14	.05	3.20

METHOD USED AND RESULTS OF TESTS.

The ores were smelted in the electric furnace that was used in smelting the native copper concentrates. The furnace is described on pages 17 to 21. The top was roofed and kept closed tightly to prevent escape of sulphur and admission of air. A condenser, which consisted simply of three rectangular horizontal chambers with several baffles in them, was attached to the furnace to condense the sulphur and catch any escaping dust. Twenty experiments were made in all. The results of five are given in Table 3.

TABLE 3.—*Results of smelting copper sulphide ores in the electric furnace, experiments 1 to 5.*

	1	2	3	4	5	Average.
Charge:						
Raw pyritic ore, pounds	12.10	8.80	7.93	6.18	5.28	....
Nodule, pounds	9.90	13.20	11.90	19.22	7.81	....
Silicious ore, pounds	3.10	5.76	8.86	10.75	12.50	....
Limestone, pounds	....	2.73	3.01	3.02	3.03	....
Matte produced:						
Copper, per cent	1.03	1.22	1.33	1.05	1.00	1.12
Iron, per cent	63.99	64.18	64.18	56.21	62.49	....
Sulphur, per cent	24.87	22.38	25.47	20.28	24.03	....
Gold, ounces per ton	.28	.72	.80	1.60	2.33	....
Silver, ounces per ton	.68	.96	2.00	4.00	3.60	....
Slag produced:						
Copper, per cent	.05	.05	.24	.13	.29	.15
SiO_2, per cent	47.88	35.25	41.75	53.00	53.05	....
FeO, per cent	40.30	41.30	39.05	25.90	26.20	....
Al_2O_3, per cent	9.24	4.40	5.09	4.01	3.57	....
CaO, per cent	1.33	10.00	10.21	10.37	10.37	....
MgO, per cent	.10	1.64	.10	.14	.11	....
S, per cent	3.84	3.66	3.21	2.23	2.36	....
Gold, ounce per ton	.02	.03	.08	.04	.08	.05
Silver, ounce per ton	.16	.32	.17	.29	.34	.25
Length of run, minutes	35	26	27	20	18	....
Mean volts on the furnace	53	51	56	70	80	62
Mean amperes on the furnace	656	635	920	792	726	745
Mean kilowatts on the furnace	31	32	51	54	56	46
Mean power factor of circuit	.89	.98	.98	.97	.96	.95
Kilowatt-hours (by meter)	18.00	13.5	25.5	17.0	15.0	17.8
Electrode consumption per short ton of charge, pounds	20.2	10.8	18.6	18.6	18.6	17.3
Weight of matte tapped, pounds	[a] 13.45	10.50	7.00	8.42	9.69	....
Weight of slag tapped, pounds	4.74	10.90	16.90	17.84	19.70	....
Sulphur volatilized, per cent	65.9	63.2	57.0	65.1	54.6	61.7
Concentration ratio	1.57	2.84	4.16	3.60	3.85	3.2
Loss of copper in slag, per cent	1.21	4.26	(b)	(b)	(b)	2.73
Copper unaccounted for, per cent	8.48	....	(b)	(b)	(b)	....
Total recovery of copper, per cent	90.31	95.74	[b] 90.30	[b] 100.00	[b] 100.00	95.3
Loss of gold in slag, per cent	2.16	4.18	11.40	5.07	(b)	5.7
Gold unaccounted for, per cent	11.75	....	10.5	0	(b)	....
Total recovery of gold, per cent	86.09	95.82	78.1	94.93	95.2	90.0
Loss of silver in slag, per cent	6.28	17.20	9.40	....	16.20	12.2
Silver unaccounted for, per cent	15.40	32.90	12.30	....	8.37	17.2
Total recovery of silver, per cent	78.32	50.10	78.30	94.50	75.10	75.2
Total value of copper, silver, and gold per ton of charge,[c] dollars	4.96	6.76	8.95	11.14	12.90	....
Value of copper, silver, and gold recovered per ton of charge, dollars	4.29	6.34	7.21	10.62	12.17	....
Total value of copper, silver, and gold recovered, per cent	86.7	94.0	80.8	95.8	94.2	90.3
Kilowatt-hours per short ton of charge	1,435	890	1,610	1,064	1,045	1,209
Kilowatt-years per ton of charge	.164	.101	.184	.13	.12	.174

---

[a] From previous run.

[b] In this and subsequent experiments the copper content of both matte and slag is high, probably because of a concentration of copper in the furnace from the numerous experiments made previously.

[c] Copper at 15 cents per pound, silver at 50 cents per ounce, gold at $20 per ounce.

DISCUSSION OF RESULTS.

In these experiments the furnace was charged and, when fusion was completed, tapped as cleanly as possible. Hanging of the charge and accumulation of material in the furnace are responsible for some results not being uniform. An attempt was made to make the results as quantitative as possible, but with a small furnace the losses affect the final calculation much more than with a furnace of commercial capacity.

SMELTING CONDITIONS, SULPHUR VOLATILIZATION, AND RATIO OF CONCENTRATION.

If the electric furnace acts simply as a melting agent in the smelting of sulphide ores, the fact will be apparent in the amount of sulphur volatilized and the ratio of concentration. In simple melting of a charge of pyrite one atom of sulphur would be driven off from the FeS_2, or 50 per cent of the sulphur in the charge would be volatilized. To determine the extent to which this reaction could be carried in the electric furnace, the crucible was roofed and was kept closed, as far as possible, in order to prevent oxidation. In the five experiments given in Table 3 an average of 61.1 per cent of the sulphur in the charge was volatilized, showing that a little more than one atom of sulphur was driven off. Hence without the introduction of an oxidizing agent the concentration ratio in the electric smelting of copper sulphide ores can not be increased much by volatilization of the sulphur in the charge.

The low ratio of concentration of 3.2, the average for five runs, verifies this statement and shows that no concentration is to be expected beyond a simple separation of gangue and matte and the loss of slightly more than one-half of the sulphur. As had been stated, there is no slagging of iron oxide beyond that of the iron oxide present in the ore as such, because there is no oxygen present to oxidize the iron sulphide formed by volitilization of the one atom of sulphur.

The smelting conditions in an electric furnace treating sulphide ore without introduction of air are then similar to those in a reverberatory furnace or a blast furnace in which the heat is supplied almost entirely by coke. The electric smelting of a copper sulphide ore under these conditions is merely a melting operation, in which reactions occur between the oxides and the sulphates of the charge and a removal by heat of a little more than one atom of sulphur.

The amount of sulphur driven off in the blast furnace, running with a reducing atmosphere, over and above that accounted for by the loss of one atom per molecule is not more than 5 per cent, whereas in the electric furnace, as these experiments show, it is about 10 per cent.

The condensation of the sulphur driven off as elemental sulphur was qualitatively possible, as was shown by analysis of the fume in the condenser, but was not quantitatively possible, because the condenser was not long enough for complete condensation of the fume, and some of it came out of the end. The uncondensed fume consisted chiefly of elemental sulphur. An average analysis of the condensed material was as follows: SiO_2, 13.96 per cent; Al_2O_3, 3.85 per cent; Fe, 9.11 per cent; CaO, 2.06 per cent; S, 46.6 per cent; Cu, 0.61 per cent; gold, 0.48 ounces per ton; and silver, 4.60 ounces per ton. A very small amount of dust from the ore was deposited at the mouth of the condenser.

COPPER, GOLD, AND SILVER LOSSES, AND LOW-GRADE MATTE AS A COLLECTOR.

The average copper content of the slag was 0.15 per cent. With proper means for settling the matte instead of tapping into a mold, the low copper content should be reduced to a still lower figure. The average percentage of copper recovered was 95.3 per cent. This shows that there was no material volatilization of copper, for the condensed fumes, which amounted to only 4.75 per cent of the total ore charged, contained only 0.61 per cent copper.

The percentage of gold recovered in the matte was 90 per cent of the total quantity of gold in the ore charged. The remaining 10 per cent was not all held by the slag, as the average loss of gold in the slag was 5.7 per cent of the total amount of gold in the ore charged. The other 4.3 per cent was probably lost mechanically in handling the charge and products. The slags contained 0.03 to 0.08 ounce of gold per ton. This indicates the collecting power of a low-grade copper matte for gold, as the copper content of these mattes varied from 1 to 1.33 per cent and averaged only 1.12 per cent. The charge contained from 0.31 to 0.83 per cent copper, the average being 0.46 per cent.

These results agree with the results of experiments by Dr. Carpenter[a] at Deadwood, S. Dak., where for several years the plant was run with mere traces of copper in the matte and never with more than 1 per cent. These slags carried from 0.025 to 0.075 ounce of gold per ton. As at Deadwood the experimental runs conducted by the writers show a lower gold loss in the slag with a greater matte fall. The results of these experiments seem to indicate that a matte containing 1 per cent copper will serve as a good collector of gold in the electric furnace and that a charge containing as low as 0.31 per cent copper may be successfully used.

---

[a] Peters, E. D., Principles of copper smelting, 1907, p. 426.

The silver recovery was not as high as that of the gold, the total percentage of silver recovered being 75.2 per cent. A large part of the silver loss must be charged to the unaccounted loss, which includes mechanical losses and loss by volatilization. The proportion of silver in the fume was higher than the proportion of gold, a fact which, with the greater unaccounted loss, indicates that there was volatilization of silver. The average silver content of the slag was 0.25 ounce per ton, which can not be considered as very high, so that the low-grade matte seems to collect the silver as well as the gold.

In order to ascertain the actual saving of values, copper is figured at 15 cents per pound, gold at $20 per ounce, and silver at 50 cents per ounce. On this basis the average value recovery for five experiments was 90.3 per cent. This would indicate that it is feasible to use a matte containing 1 per cent copper in the smelting of an ore for recovery of gold and silver. With a higher matte fall the recovery would be greater. The loss in the slag seems to depend mostly on the proper separation of slag and matte. With an acid slag this separation is easy, but with a basic slag, as the specific gravity of the slag and that of the matte approach each other, separation becomes more difficult. As was stated by a recent writer on the subject, "Copper is not essential in mattes which accompany acid slags, but with basic slags it may be necessary."

ELECTRODE CONSUMPTION.

The average electrode consumption was 17.3 pounds per ton of charge, the lowest figure obtained being 10.5 pounds. In practice, with a large furnace the electrode consumption should be easily reduced to 5 pounds per ton of charge. The reduction of iron by the carbon electrode has been shown, in the experiments previously discussed, to be of small account.

POWER CONSUMPTION.

The power consumption was abnormally high in all of the experiments given in Table 3, with the exception of No. 2, because the runs were continued longer than was necessary, owing to the difficulty of telling when fusion was complete with the furnace top roofed. A power consumption of 890 kilowatt-hours per ton was attained several times in experiments not given in this bulletin and may be taken as being about the best it was possible to obtain with the furnace used. The efficiency of this furnace had been determined to be 36.76 per cent. On the basis of a properly designed furnace of several thousand kilowatts capacity in which an efficiency of 70 per cent should be attained, the power consumption would be (890×36.76)÷70=480 kilowatt-hours per ton of charge smelted, or 0.055 kilowatt-years. From the general trend of 20 experiments on the smelting of charges similar to those given in Table 3, there seems to be a slight increase in power consumption with a higher proportion of pyrite in the charge.

CONCLUSIONS.

1. The smelting of sulphide ores in an electric furnace without admission of air consists simply of melting the charge, volatilization of about 60 per cent of the sulphur as elemental sulphur, and separation of the slag and matte.
2. The ratio of concentration is simply that possible from separation of matte and slag, reaction of oxides with sulphates and sulphides, and the volatilization of about 10 per cent more than one-half of the molecular sulphur, with no formation of iron oxide to enter the slag, because there is no oxidizing agent present to oxidize the iron sulphide.
3. Qualitatively, it is possible to condense some of the elemental sulphur driven off.
4. The loss of copper by volatilization and in the slag is low.
5. A matte containing about 1 per cent of copper from a charge containing 0.30 per cent copper makes a good collecting agent for gold and silver, if a clean separation of slag and matte is obtained.
6. There is very little loss of gold by volatilization in the electric furnace, but some silver is lost in this way. In a larger furnace with closer temperature regulation there would probably be no loss.
7. The electrode consumption in the smelting of a sulphide ore is low and in practice need not exceed 5 pounds per ton of charge.
8. In a large commercial furnace the power consumption for most ores would be about 480 kilowatt-hours per ton of ore, or 0.055 kilowatt-years.

COMPARISON OF ELECTRIC FURNACE WITH REVERBERATORY FURNACE AND BLAST FURNACE AS A MELTING AGENT.

So far only the use of the electric furnace as a melting furnace in the treatment of copper ores has been considered. From what has been stated, the authors believe that they are justified in making the following statements as to the possibility of using the electric furnace for this purpose.

1. Native copper, oxide, or sulphide ores of copper can be melted just as efficiently, and perhaps even more efficiently, in the electric furnace than in either the reverberatory furnace or the blast furnace.
2. The reactions desired in reverberatory smelting, or ordinary blast-furnace smelting, can be obtained just as well and perhaps better in the electric furnace than in either of those furnaces.

3. The loss of electrodes is small, varying from 5 to 10 pounds per ton of ore smelted, and the presence of the carbon electrode does not cause enough reduction of iron to be troublesome or to increase the consumption of electrical energy appreciably.

4. The losses of copper, gold, and silver by volatilization and in the slag would be no greater, as is shown in all the experimental work cited, than they are in reverberatory smelting or ordinary blast-furnace smelting.

5. A matte containing as low as 1 per cent of copper can be used as a collecting agent for gold and silver in the electric furnace as well as in the combustion furnace.

6. The cost would depend entirely on the nature of the ore to be treated and the relative cost of coal or coke and electrical energy. In general, from the work done in the experiments, it may be said that from 500 to 700 kilowatt-hours per ton of charge, depending on the nature of the ore, would be required for smelting copper ore.

SEMIPYRITIC SMELTING OF SULPHIDE ORES.

PRINCIPAL FEATURES OF THE PROCESS.

In discussing the smelting of copper ores by ordinary blast-furnace smelting, the fact has been noted that the process consists essentially in melting down the charge, and that during the melting certain reactions take place between the constituents of the charge which bring about a concentration of the copper and precious metals (if the latter are present) into a matte and the excess iron and the gangue materials into a slag, that in this method of smelting the heat necessary for carrying out the process is obtained by the combustion of coke at the tuyères, and that the only purpose in using the blast is to supply the oxygen required for combustion of the coke. In other words, the oxygen entering the tuyères plays no part in the reactions which take place in the furnace so far as the constituents of the charge other than coke are concerned.

Such being the case, the essential feature of the process is the melting down of the charge and, so far as the reactions of the process are concerned, the charge could be melted down just as well in an electric furnace as in a blast furnace. Those processes of copper smelting in which the air entering at the tuyères not only furnishes the oxygen necessary for producing heat, but also that required for bringing about the reactions which take place during the melting, and which result in the production of a matte and a slag, as in ordinary blast-furnace smelting, will now be considered. In this connection it is to be remembered that no matter what process is employed in obtaining metallic copper (as a final product) from a sulphide the three essential features of the process are: (1) The removal of sulphur; (2) the oxidation of the iron with which the sulphur was combined; and (3) the removal of this iron oxide by causing it to unite with silica to form a slag.

Hence, as stated by Peters[a], the first step in the smelting of a sulphide ore of copper must be to oxidize it. In the process that will now be considered the object is to bring about the required degree of oxidation and the melting at practically the same time, and to obtain either the whole or a part of the heat required for the process from the oxidation of the iron and sulphur contained in the ore. As is well known, if practically all the heat necessary for melting down the charge is obtained in this manner, the process becomes what is known as pyritic smelting, and if only in part, as semipyritic smelting. However, Peters[b] states that, so far as he is aware, in all pyrite furnaces of the world a small amount of fuel (usually coke) is added to the charge, and this amount may vary anywhere from 0.5 per cent of the weight of the charge up to a proportion that might be actually enough to melt the ore without any heat at all being derived from the sulphides.

SUBSTITUTION OF ELECTRIC HEAT FOR HEAT DERIVED FROM COKE.

The question, therefore, that presents itself in connection with the smelting of copper sulphide ores in the electric furnace is to determine whether electric heat may be used to replace the heat which is derived from the combustion of coke in pyritic and semipyritic processes. In other words, whether it would be possible, and if so, whether it would be commercially feasible, to carry out these processes in an electric furnace so constructed as to permit the use of a blast, thus obtaining as much heat as possible from the oxidation of the sulphur and iron, any additional heat required being supplied by electric energy.

To begin with, let it be assumed that the construction of the furnace is similar to that of a modern copper blast furnace and is practically the same for the upper part of the furnace, including the tuyères. Below the tuyères, *a*, the furnace could be constructed as shown in figure 5. The electrodes, *b*, extend down into the crucible, *c*, and are arranged along the sides of the crucible as shown in figure 6.

At this point will be considered briefly the behavior in the electric furnace of a charge that would be suited to semipyritic smelting; that is, one in which so much coke would have to be used that "its influence upon the oxidizing power of the focus begins to be plainly discernible," which, as stated by Peters,[b] is "the division line between true and partial pyrite smelting." Inasmuch as no coke would be used in a charge smelted in an electric blast furnace, the point to be determined is how the charge would act when such a furnace was used, and if the desired results could be obtained, as before stated, in a feasible and economical manner.

---

[a] Peters, E. D., Principles of copper smelting, 1907, p. 220.

[b] Peters, E. D., loc. cit., p. 214.

BEHAVIOR OF A CHARGE SMELTED WITHOUT COKE.

The object aimed at in operating a copper blast furnace in semipyritic smelting is to supply enough blast to completely oxidize the coke, and also to oxidize as much of the iron sulphide for slag-forming purposes as can be spared from the matte. If, therefore, there were no coke to be oxidized, only enough air need be forced through the tuyères to effect the required degree of oxidation of sulphur and iron.

In general, it may be assumed, as does Peters,[a] that in semipyritic smelting the furnace is "provided with but a scanty supply of pyrite" and that it produces a slag "rather high in silica and earths" and "consequently would require a considerable amount of coke." In the electric blast furnace, as before stated, coke would not be used, the equivalent heat value of the coke being obtained from electric energy instead. If, therefore, the electric blast furnace be supplied with a charge that is suited to semipyritic smelting, what difference may be expected in the behavior of the charge as compared to the behavior of a similar charge when smelted in a copper blast furnace with coke? In making the comparison the behavior and effect of the coke itself will first be considered.

EFFECT OF COKE IN THE BLAST FURNACE.

Peters[b] discusses the action of coke in the blast furnace as follows:

> The amount of coke present carries the melting process high up above the proper zone of oxidation, and to regions where there is yet no formation of FeO. Half-fused masses of acid earthy silicates are formed, and much, in some cases all, of the free silica is combined with the alumina, lime, magnesia, manganese, alkalis, and already oxidized iron, all of which substances are likely to be present in the ore mixture. It is not that the affinity of the silica is satisfied in forming these preliminary, temporary, refractory acid silicates, but the edge of its appetite is blunted and the eventual formation of ferrous silicate seems to proceed somewhat sluggishly, even when ample air is blown into the furnace.
>
> As may be imagined the main endeavor of the metallurgist in this type of smelting is to keep the proportion of coke to ore as low as possible, not merely because coke costs money, but still more because any excess of coke causes a lowering in the grade of matte, due to its interference with the oxidation of the sulphides. A furnace in proper condition and running on a suitable charge is extraordinarily sensitive on this point. The increase of the coke from a standard charge of 60 pounds per 2,000 pounds of ore up to 65 pounds per 2,000 pounds of ore may be followed—as has come under my personal observation—by a dropping of the grade of matte from 35 per cent copper and a raising of the silica contents of the slag from 41 per cent. This results, of course,

---

[a] Peters, E. D., Principles of copper smelting, 1907, p. 326.

[b] Peters, E. D., loc. cit., p. 333.

from the consumption by the new coke of a certain amount of oxygen which previously had been employed in burning iron sulphide. Under this new condition this iron sulphide entered the matte at the same time, robbing the slag of just so much FeO.

REACTIONS IN THE ELECTRIC FURNACE.

If such a charge be smelted in the electric blast furnace without coke and with just enough blast to supply the oxygen required for oxidation of the sulphur and iron, there would doubtless be no "half-fused masses of acid, earthy silicates, formed," as stated by Peters, and since, as shown by him, the control of the coke is a matter of great importance, due to the "extraordinary sensitiveness of the furnace on this point" and its resultant great irregularities, it would seem that it would be a great advantage to do away, if possible, with coke. If coke can be dispensed with and the smelting be done in some such furnace as the one shown in figure 5, the charge would probably enter the tuyère zone of the furnace practically unaltered except, perhaps, for loss of elemental sulphur. Inasmuch as the sulphides are easily melted (950° C.), it may be assumed that there would be enough heat present from the oxidation of the sulphur and iron and radiated from the crucible to cause the iron sulphide to melt and to become oxidized to FeO and then be instantly seized by SiO_2 to form a slag. However at a temperature of 950° C. the result might be the formation of a silicate high in SiO_2, due to the fact that at low temperatures the saturation point of silica for iron is low, and this silicate would perhaps "freeze," so to speak, at once and descend into the crucible and be gradually melted in the neighborhood of the electric current. In other words, there would be formed above the tuyère zone the artificial boshes observed by Sticht, Freeland, and others, and described by Peters,[a] thus contracting the smelting and slag forming area "to a comparatively narrow opening running along the middle of the furnace shaft." Sticht states that these boshes "are the contact lines between the active combustion zone and the relatively dead part of the shaft above" and that the absence of coke (speaking of pyrite furnaces) accentuates the sharp division line between the active and stagnant regions of the furnace. Reasoning by analogy, it would seem that this division line would be as pronounced, if not more so, in an electric blast furnace, such as the one under discussion, as in the pyrite furnace.

COMPARISON OF ELECTRIC BLAST FURNACE WITH THE COPPER BLAST FURNACE FOR SEMIPYRITIC SMELTING.

METALLURGICAL CONSIDERATIONS.

To recapitulate, there does not seem to be any metallurgical reason why the chief objects of the pyrite smelter can not be carried out in an electric copper blast furnace as well as in a coke copper blast furnace; namely, to melt the great mass of SiO_2 and inert earths, and to oxidize enough of the sulphides in the charge to insure a suitable matte, incidentally obtaining the heat evolved by the oxidation. On the other hand it would seem that the difficulties ordinarily encountered in operating a pyrite furnace might be avoided when using an electric blast furnace, that is, the difficulties which arise when too much or too little coke is added to the charge. Moreover, electric heating not only permits "introducing heat into the furnace without at the same time robbing the combustion zone of oxygen"—in regard to which Peters[a] states, "nothing would be so welcome to the furnace man as to do this"—but would also permit of the heat being entirely under control and easily regulated and thus avoid "freeze-ups" with their consequent vexations and costly delays. By this latter statement it is not meant that any sort of charge could be put through the furnace and not "freeze," an idea which seems to be quite prevalent in regard to electric furnaces, but that, if the charge be properly calculated, a much wider variation in the composition of the slag from that calculated would be permissible than would be the case in ordinary blast-furnace smelting.

---

[a] Peters, E. D., Principles of copper smelting, 1907, pp. 234, 235.

MECHANICAL CONSIDERATIONS.

By referring to figures 5 and 6 it will be noted that the chief difference in the construction of the electric blast furnace from that of the ordinary blast furnace would be in the part below the tuyères; in other words, the crucible of the furnace. Due to the fact that electric furnace construction has received the attention of some of the very best mechanical and electrical engineers, and because a crucible based upon the principle of the design shown in figure 5 is now extensively used in the electric iron reduction furnaces of Norway and Sweden, the writers believe that no difficulty would be experienced in this respect. Various methods and arrangements can be used for connecting up electrodes. If this be true, there remains to be considered only the matter of costs.

COMPARISON OF COSTS.

Inasmuch as it has already been stated that the use of the electric furnace as a competitor of the blast or combustion furnace, or that it should replace the copper blast furnace, is not advocated by the writers, it will be evident that a comparison of costs is made simply for the purpose of giving some idea as to the outlay that would be necessary to erect and operate an electric furnace plant for the purpose of smelting copper ores.

---

[a] Peters, E. D., Principles of copper smelting, 1907, p. 334.

Naturally, the first thing to be considered is whether it would be feasible to attempt to substitute electrical energy for coke, due to the cost of the former.

COST OF PLANT.

The cost of an electric-furnace plant would be about the same as the cost of a regular plant plus the cost of electrical installation but exclusive of the cost of the generating plant, as it is assumed that it would be possible to purchase electric power from some other company, or, if not, that the generating plant be considered as a separate organization selling power to the smelter at so much per unit. Therefore by electrical installation is meant the cost of transformers, bus bars, cables, instruments, etc. In order to have a basis for computing this cost, it is assumed that the furnace is to smelt 384 tons of charge a day, the composition of the charge being as follows:

Composition of charge.

	Per cent.
Cu	5.21
SiO_2	26.41
FeO	18.60
S	11.46
Al_2O_3	4.26
CaO	17.49

This is the average composition of the entire blast-furnace charge that was smelted at the Washoe smelter, Anaconda, for several months.[a] At the Washoe plant 8.2 per cent of coke was used. The amount of electrical energy that would be required to smelt a charge of this nature in an electric furnace will now be considered.

At the Washoe smelter the furnaces formerly used were 56 by 180 inches in cross section (hearth area 70 square feet) and smelted on an average a little less than 400 tons of charge daily, or 5.6 tons per square foot of the hearth area.[b]

AMOUNT OF ELECTRICAL ENERGY REQUIRED TO REPLACE COKE.

Since 8.2 per cent of coke was required at the Washoe smelter to smelt 1 ton of the above charge, the consumption of coke per ton of charge was 2,000×8.2=164 pounds.

The coke used contained 80.24 per cent of fixed carbon; therefore, the number of pounds of carbon in 164 pounds of coke is 164×80.24=131.59. If 1 pound of carbon be completely burned to carbon dioxide, 8,100 pound-calories are obtained. Therefore the number of pound-calories that would be obtained from the 131 pounds of carbon contained in the 164 pounds of coke is 131×8,100=1,061,100. As 1 kilowatt-hour is equivalent to 1,897 pound-calories, it would require 1,061,100 ÷ 1,897 = 559 kilowatt-hours to replace the theoretical calorific value of the 164 pounds of coke. However, as a copper blast furnace under the most favorable conditions probably does not have an efficiency of over 50 per cent, the amount of energy really obtained from the coke, so far as work performed in the furnace is concerned, is only 530,550 pound-calories, which is theoretically equivalent to $\frac{530,550}{1,897}$, or 280 kilowatt-hours per ton. Inasmuch as the efficiency of the electric furnace of this type may be as much as 85 per cent and as that of an open-top ferrosilicon furnace is said to be about 60 per cent,[a] it is fair to assume that the efficiency of an electric furnace, such as is shown in figure 3, would be 20 per cent greater than that of an ordinary blast furnace, or about 70 per cent as compared with 50 per cent for the blast furnace. If this be true, then the theoretical 280 kilowatt-hours needed to smelt 1 ton of charge would have to be increased 1.42 times ($280 \times 1.42 = 397$), or, say, in round numbers, 400 kilowatt-hours would be required to smelt 1 ton of charge. Considering that part of the heat in this case is supplied by combustion of sulphides, the figures agree closely with the 480 kilowatt-hours calculated from the experiments on melting only. As 16 tons of charge per hour are to be smelted, the constant load on the furnace would be $400 \times 16 = 6,400$ kilowatt-hours, and as the power supply would doubtless be three phase, this would mean that the electrical equipment should consist of three 2,500-kilowatt variable voltage transformers. Transformers of this capacity would allow ample margin for sudden overloads, instruments, bus bars, cables, and miscellaneous supplies.

---

[a] Peters, E. D., Practice of copper smelting, 1911, p. 264.

[b] Peters, E. D., Principles of copper smelting, 1907, p. 156.

The cost of this equipment at the plant would, of course, depend upon the location of the plant and would be the factory costs plus transportation charges.

As to the total cost of the plant, that would also, of course, depend, as in every instance, upon the location of the plant. In short, as before stated, it would be the cost of an ordinary copper blast-furnace plant plus the cost of the electrical installation. The cost of the furnace itself would be no more than that of a coke blast furnace. As only enough air is blown in to oxidize the iron and sulphur, the blower capacity would not need to be so large as for a regular blast furnace.

COST OF SMELTING.

It may be stated that the cost of coke and the cost of electrical energy are about on a par when coke costs $7 a ton and electrical energy costs $0.15 per kilowatt-hour, or $13 a kilowatt-year; that is, when the ratio of the cost of coke per ton to the cost of power per kilowatt-year is about 1:1.8. Any advantages which there may be in the use of an electric blast furnace instead of an ordinary blast furnace, such as the saving in blowing by reason of not having to furnish air for burning the coke, will be disregarded, and it is assumed that the cost of electrodes and of the electricity on the one hand, and the cost of its equivalent in heating value of coke on the other, would be equal; in other words, that the cost of electrodes and electricity would balance the cost of the amount of coke that would be necessary to smelt the same quantity of ore.

---

[a] Conrad, W., and Piels, W., La fabrication du ferrosilicium à haute teneur au four electrique: Revue Mét., vol. 9, 1912, p. 362.

Cost of electrodes.—The average consumption of electrodes in smelting iron ore at Trollhättan, Sweden, is about 10 pounds per ton of iron produced. Assuming that 1 ton of iron is equivalent to 2 tons of iron ore, the consumption of electrodes per ton of charge smelted in a furnace such as the one under discussion would not be over 5 pounds per ton. If it is assumed that the electrodes do not cost over 6 cents per pound, which allows a fair margin for transportation over their cost at the factory, the cost of electrodes would be about 30 cents per ton of charge smelted. The consumption would probably be considerably less than 5 pounds per ton, as in an experiment performed by the writers in which air was blown into the furnace, the electrode consumption was only 2 pounds per ton of ore treated. Such being the case, if the combined electrical energy and electrode cost is not to exceed the equivalent coke cost, with coke at $9 a ton, the cost of electrical energy would be $9 \times 1.8 = \$16.20$ a kilowatt-year, minus the cost of electrodes, or about $16. Compared on the basis of calories, if the coke contains 80.24 per cent fixed carbon, it would contain 1,604.8 pounds of carbon per ton of 2,000 pounds, and this carbon would, if completely burned to CO_2, give a calorific value of about 13,000,000 pound-calories. As one kilowatt-year of electric energy is equivalent to 16,616,000 pound-calories, it would require something like 1.2 tons of coke containing 80.24 per cent fixed carbon to equal in calorific value a kilowatt-year, if it be assumed that all the carbon of the coke is completely burned to CO_2, a condition which rarely occurs in practice. It has been determined from actual practice that from 1.5 to 1.8 tons of coke are required to yield the same number of useful calories as may be obtained from 1 kilowatt-year of electrical energy.

THE USE OF THE ELECTRIC BLAST FURNACE IN THE SMELTING OF PYRITIC ORES.

As was previously stated, in all true pyritic smelting a certain amount of fuel, usually coke, that varies with the nature of the ore is added to the charge. Assume, for the purpose of this discussion, that the ore being treated is entirely suited to pyritic smelting and that it is not necessary to add more than 0.5 per cent of coke to the charge, could such an ore be treated as well in an electric blast furnace as in an ordinary furnace, assuming that the costs would be the same in each case? As what has been stated in regard to the construction of the furnace and the costs of applying the process is as applicable to true pyritic as it is to semipyritic smelting, the discussion will be limited to the metallurgical and chemical features involved.

The nature of the atmosphere in a pyrite furnace will first be considered. As the air enters the tuyères practically all of its oxygen enters into immediate combination with sulphur and iron to form SO_2 and FeO. Although some oxygen escapes combination, the amount is not sufficient to support combustion within the furnace, as has been shown by Sticht and others.[a] So much, then, for the nature of the atmosphere within the furnace.

The changes which take place in the charge as it descends from the charging door to the fusion zone are few and may briefly be stated as follows:

1. The iron sulphide loses one-half of its sulphur as elemental sulphur and becomes FeS.
2. The chalcopyrite loses about one-fourth of its sulphur and becomes practically a mixture of Cu_2S and FeS.
3. The silica is unchanged.
4. The coke is for the most part consumed in the upper zone of the furnace, not by the oxygen of the air, as no free oxygen exists in that part of the shaft, but by the O from SO_2; that is, the carbon of the coke reduces the SO_2, the products of the reaction being S and CO, and this CO reacts with more SO_2, forming S and CO_2. Aside from these reactions, which are of no great importance in the chemistry of the process, the chief office of the coke, as pointed out by Sticht,[b] "is apparently to heat up the sulphides and the quartz in preparation for their active oxidation deeper in the furnace." If, therefore, coke was omitted from the charge, this preparation of the sulphides and the quartz would not take place, and it becomes necessary to determine how detrimental to the process this lack of preparation would be.

In order to answer this question it must be borne in mind that in true pyritic smelting there is "no heat to spare," and that although, as pointed out by Sticht, the heat evolved by the combustion of the coke by the oxygen of sulphur dioxide is only one-third as much as it would be if the oxygen were furnished direct by the blast, and that it is given off at a point considerably higher than the focus of the furnace, it nevertheless "assists in preparing the charge for the reactions which take place in the focus of the furnace, for with 1 per cent of coke in the charge enough heat is generated to supply one-third of the heat required to melt the entire pyrrhotite contents of the charge." This extra heat "doubtless furnishes just the necessary aid to bridge the operation over some critical point." From this it is evident that the office of the coke, then, is solely for the purpose of furnishing heat. Inasmuch as the nature of the charge in true pyritic smelting is such as to demand the oxidation and removal of a large excess of iron as silicate; and as it is necessary to cause the silica present to unite with as much FeO as possible, due to the fact that as a rule silica-bearing materials, which often are barren and hard to obtain, have to be added for slag-forming purposes, and as the saturation point of silica for iron oxide is greater, the higher the temperature attainable in the pyritic furnace; it is quite necessary that the reactions in the melting zone of the furnace proceed as energetically as possible in order to meet these requirements and to provide enough heat to keep the process going. If, therefore, pyritic smelting be attempted in an electric blast furnace it would be necessary to supply the heat from the electric current in such a manner as to insure there being enough heat at the focus to carry on the reactions at that point in the same manner as if coke had been added to the charge. The writers are of the opinion that it would be possible and perfectly feasible to do this in a furnace of the type shown in figure 5. Moreover, the use of electric heating would permit of a more uniform operation of the furnace than is now possible, for with the electric current it would be an easy matter to quickly increase or decrease the heat required for the successful operation of the furnace. In this way there could be maintained the "degree of concentration at a constant" which, as pointed out by Sticht, is very important, but is extremely difficult to do. Also the troubles could be avoided that arise from the constant fluctuations "which are bound to occur and which at present demand unbroken attention and frequent changes in the charge, especially in its proportion of silica, due to the fact that in true pyrite smelting there is no heat to spare," because with the electric blast furnace it would be possible as just stated, to increase or decrease the heat whenever it would be necessary to do so in order to meet these fluctuations.

---

[a] Peters, E. D., Principles of copper smelting, 1907, p. 225.

[b] Peters, E. D., loc. cit., p. 227.

CONCLUSION.

The electric smelting of copper ores is nothing more than the substitution of electric heat for the heat derived from the combustion of carbon. Inasmuch as the carbon which is used either in the reverberatory furnace or in the blast furnace plays no important part in the reactions that take place in these furnaces, there is no reason metallurgically why electric heat may not be substituted for the heat derived from the combustion of carbon. In fact, as the authors have attempted to point out, in some cases the reactions would take place to better advantage in the neutral atmosphere of the electric furnace than in the reducing or partly reducing atmosphere of the combustion furnace. Therefore, the practicability of using the electric furnace for the smelting of copper ores would largely depend on the relative cost of coke and electric power. As the use of the electric furnace is not advocated as a competitor of the combustion furnace, but as a substitute for it, in those localities where it is not advisable, because of the high cost of fuel, to use the combustion furnace, there is no apparent reason why the electric furnace may not be developed as a substitute for the combustion furnace where the conditions are such as to warrant its use, especially in the treatment of copper-bearing ores. In this connection it is to be remembered that the development of the electric furnace in the iron industry for the reduction of iron from its ores was due to necessity. As a matter of fact, the field for the electric furnace in the reduction of iron from its ores is a limited one. Perhaps the same is true as regards the possible application of the electric furnace to the treatment of copper ores, but, judging from the comparative costs, as shown in the preceding pages, it would seem that the possibilities of the electric furnace for the treatment of copper ores are greater than those for the treatment of iron ores, because there is not so great a difference between the cost of coke and of electric power in copper-mining districts as there is in iron-smelting centers. Also the cost of electric power is constantly becoming less, through improvements in gas engines and steam turbines, so that in districts where water power is not plentiful but cheap fuels unsuited to coke making are available, it may be found more advantageous to use electric heat than the heat derived from the combustion of coke.

It is sincerely hoped by the writers, although it is impossible at this time to present but few facts, that the comparative study herewith presented may serve to stimulate interest in the subject of the electric smelting of copper ores and to cause others to attempt a further investigation of the subject. As a result of their investigation, the writers are convinced that experimental work on a larger scale would lead to the development of an electric blast furnace which in some cases could be used to better advantage for smelting sulphide ores of copper than the combustion blast furnace.

PUBLICATIONS ON MINERAL TECHNOLOGY.

A limited supply of the following publications of the Bureau of Mines is temporarily available for free distribution. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

BULLETIN 47. Notes on mineral wastes, by C. L. Parsons. 1912. 44 pp.

BULLETIN 53. Mining and treatment of feldspar and kaolin in the southern Appalachian region, by A. S. Watts. 1913. 171 pp., 16 pls., 12 figs.

BULLETIN 64. The titaniferous iron ores in the United States, their composition and economic value, by J. T. Singewald, jr. 1913. 145 pp., 16 pls., 3 figs.

BULLETIN 70. A preliminary report on uranium, radium, and vanadium, by R. B. Moore and K. L. Kithil. 1913. 100 pp., 2 pls., 2 figs.

BULLETIN 71. Fuller's earth, by C. L. Parsons. 1913. 38 pp.

BULLETIN 77. The electric furnace for metallurgical work, by D. A. Lyon, R. M. Keeney, and J. F. Cullen. 1914. 216 pp., 56 figs.

BULLETIN 84. Metallurgical smoke, by C. H. Fulton. 1914. 92 pp., 6 pls., 15 figs.

TECHNICAL PAPER 41. Mining and treatment of lead and zinc ores in the Joplin district, Missouri, a preliminary report, by C. A. Wright. 1913. 43 pp., 5 figs.

TECHNICAL PAPER 50. Metallurgical coke, by A. W. Belden. 1913. 48 pp., 1 pl., 23 figs.

TECHNICAL PAPER 60. The approximate melting points of some commercial copper alloys, by H. W. Gillett and A. B. Norton. 1913. 10 pp., 1 fig.

TECHNICAL PAPER 81. The vapor pressure of arsenic trioxide, by H. V. Welch and L. H. Duschak. 1914.

INDEX.

A. Page.

- Alumina, in slag, effect of 30, 34
- Anaconda, Mont., reverberatory furnaces at, thermal efficiency of 12
  - smelter at, coke used in 71
    - composition of charge in 71
- Arsenic, recovery of 57, 58

B.

- Blast furnace, relative merits of 51, 65, 66
  - smelting of ores in 9, 10
    - chemical changes during 11
    - cost of 46, 47
    - features of 48, 49
    - losses in 51
  - zones in shaft of 11
- Bureau of Mines, experiments of 60

C.

- Carbonate ores, process of smelting 8, 9
- Carpenter, —, experiments by 63
- Chalcopyrite, chemical composition of 10
  - results of smelting 10
- Coke, in blast furnace smelting, action of 68, 69
    - consumption of 71
  - in pyritic smelting, function of 74, 75
    - possibility of eliminating 69
  - proportion of, to ore 68, 69
- Copper losses, in electric smelting 26, 42, 57
    - factors affecting 22, 23, 29-32
  - in slag 27, 28, 63
- Copper, proportion of, in slag 35
  - recovery of, in electric smelting 61
- Copper concentrates, chemical analyses of 22
  - experimental smelting of, apparatus for 20
    - cost of 46, 47
    - details of 27, 28
    - electric furnace for 43, 44
      - advantages of 45, 46
      - figures showing 44, 45
    - grades used in 21
    - methods for 45, 46
      - factors governing 46
    - power consumption in 35, 37, 43
      - variations of 38
    - results of 27, 28
    - without flux 23
- Copper ores, analyses of 56
  - classes of 8
  - concentration of 14
  - proportion of in charge 57
  - recovery of arsenic from 57, 58

Page.

- Copper ores, smelting of, furnace used in 59
    - heat required for 37
    - in electric furnace, conditions determining 76
      - experiments on 16
      - factors involved in 8
    - method of 59
    - results of 60
- Crucible for furnace, details of 17
  - support for 18, 19

D.

- Deadwood, S. Dak, copper smelting at, results of 63, 64

E.

- Electric blast furnace, construction of 67
  - cost of equipment for 72
  - figures showing 52, 53
  - power consumption of 71
  - relative cost of 70, 71
  - semipyritic smelting in, advantages of 70
    - cost of 72, 73
    - discussion of 68
- Electric furnace, description of 43, 44
  - experimental, description of 17-20
    - figures showing 18, 19
    - operation of 16, 38, 39
    - power factor of 39
    - walls of 19
  - figures showing 44, 45
  - heat efficiency of 38
  - smelting copper ores in, cost of 66
    - factors involved in 13
    - losses from 51, 53
    - possible disadvantages of 12, 13
    - relative advantages of 65, 66
  - thermal efficiency of 12
  - use of, factors governing 7, 8
- Electrodes, consumption of 27, 28, 42, 61, 64, 65
    - factors affecting 39
    - variations in 34
  - cost of 73
  - device for regulating 20
  - holders for 20
  - reduction of iron by 32, 33, 55, 56
    - factors affecting 33

F.

- Ferrosilicon, from copper slags 39-42
    - experiments in producing 40, 41
    - impracticability of 41, 42
- Flux, elimination of, in smelting 23, 24
  - *See* Hematite; Limestone; Silica.

Page.

Freeland, —, on electric blast furnace smelting 69
Furnaces. *See* Blast furnace; Electric furnace; Reverberatory furnace.

G.

Galena, chemical composition of 10
results of smelting 10
Gangue, acid, use of, in smelting copper ores. 58
Gold, loss of, in slag 61, 63

H.

Hematite, chemical analysis of 22
use of, as flux 25, 26, 34, 42
Hofman, —, on melting point of slag 36

I.

Iron, proportion of, in copper smelted 32
factors affecting 32
reduction of, by electrode, factors affecting 33
Iron ores, smelting of, in electric furnace, limitation on 76
Iron oxide, reduction of 23
effect of base on 34

L.

Limestone, use of, as flux 25, 26, 42
advantage of 31, 32
results of 34, 35, 36
Livet, France, copper smelting at, charge used in 55
tests of 54
results of 51, 55

M.

Matte, recovery of metal by 63
Michigan, smelters in, capacity of 14
smelting of concentrates at 13, 14

O.

Oxide ores, smelting of 8, 9
Oxygen, in slag, effect of 29, 30, 31

P.

Peters, E. D., on copper blast-furnace smelting 48, 49, 51
on removal of sulphur in copper ores 49, 50
on smelting of sulphide ores 9, 10, 48, 67
on smelting with electric blast furnace ... 69, 70
on smelting with reverberatory furnace .. 11, 12
Power consumption, calculation of 72
cost of 73
effect of size of furnace on 38
factors affecting 64, 65
maximum, conditions governing 57
minimum, conditions governing 57
relation of, to oxygen in slag 37
Pyrite, chemical composition of 10
Pyritic ores, smelting of 74
atmosphere of furnace during 74
chemical changes during 74
in blast furnace 73, 74
in electric furnace 75
conditions governing 75
purpose of 70
yritic smelting, definition of 67

R. Page.

Reverberatory furnace, method of operating. 14
merits of 65, 66
proper function of 12
smelting of ores in 12
cost of 47
objections to 12
thermal efficiency of 12
treatment of slags from 15

S.

Schilowski, J., experiments by 56-58
on recovery of arsenic from ore 57, 58
Semipyritic smelting, definition of 67
discussion of 68
Silica, use of, as flux 24
effect of 34
Silicate ores, smelting of 8, 9
Silver, loss of, by volatilization 65
in slag 61, 63
recovery of, in copper smelting 64
Slag, acidity of, effect of 24, 25, 30
analyses of 27, 28, 35, 36, 40, 55
basicity of, effect of 25, 26
difficulty of utilizing 39-42
losses in 29, 53, 61, 63
conditions governing 64
melting point of 36
proportion of copper in 35
removal of, from furnace 16, 17
treatment of 15
Stephan, M., experiments of 9
on smelting of nonferrous ores 59
Sticht, —, on electric blast-furnace smelting .. 69
on smelting of pyritic ores 74, 75
Sulphide ores, analyses of 60
smelting of, chemical changes during 11
concentration by 61, 62, 65
electrode consumption in 61
experiments in 53-60
features of 66, 67
in blast furnace 9, 10
in electric furnace 65
conditions governing 62
methods for 9, 10, 11, 61
Sulphur, condensation of 63, 65
removal of, from sulphide ores 9, 10, 49
methods of 50
volatilization of 61, 62

T.

Trollhättan, Sweden, smelter at, cost of electrodes in 73

V.

Vattier, —, experiment by, on electric furnace in copper smelting 54-56
Volatilization, losses from, in electric furnace. 51, 53
factors affecting 22

W.

Wolkoff, W., smelting of copper sulphide ores by 58, 59

O

East Engin
Library
TN
23
.U58

Bulletin 85

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, DIRECTOR

ANALYSES OF MINE AND CAR SAMPLES OF COAL COLLECTED IN THE FISCAL YEARS 1911 TO 1913

BY

ARNO C. FIELDNER, HOWARD I. SMITH, ALBERT H. FAY,
and SAMUEL SANFORD

WASHINGTON
GOVERNMENT PRINTING OFFICE
1914

The Bureau of Mines, in carrying out one of the provisions of its organic act—to disseminate information concerning investigations made—prints a limited free edition of each of its publications.

When this edition is exhausted copies may be obtained at cost price only through the SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C., who is the authorized agent of the Federal Government for the sale of all publications.

The Superintendent of Documents IS NOT AN OFFICIAL OF THE BUREAU OF MINES. His is an entirely separate office and he should be addressed:

SUPERINTENDENT OF DOCUMENTS,
Government Printing Office,
Washington, D. C.

The general law under which publications are distributed prohibits the giving of more than one copy of a publication to one person. Additional copies must be purchased from the Superintendent of Documents. The price of this publication is 45 cents.

First edition. August, 1914.

Cost Engineer
of
S. J. Ware
7-21-48

CONTENTS.

Page.

Sampling and analytical methods, by ARNO C. FIELDNER........ 1
  Introduction........ 1
  Acknowledgments........ 2
  Collection of samples........ 2
    Method of mine sampling followed by Bureau of Mines........ 3
    Collection of car samples........ 3
    Method of sampling followed by the United States Geological Survey.. 3
  Relation of mine samples to commercial shipments........ 3
  Analytical methods........ 5
    Preparation of laboratory samples........ 5
    Determination of moisture........ 6
    Ash determination........ 6
    Determination of volatile matter........ 6
      Apparatus........ 6
      Modified method for lignites and subbituminous coals........ 7
      Use of the electric furnace........ 7
    Determination of fixed carbon........ 9
    Sulphur determination........ 9
    Determination of carbon and hydrogen........ 9
    Nitrogen determination........ 9
    Determination of calorific value........ 9
  Interpretation of analytical results........ 10
    Proximate analysis........ 10
      Moisture content........ 11
      Ash........ 11
        Inherent impurities........ 12
        Extraneous impurities........ 12
      Volatile matter and fixed carbon........ 12
      Sulphur........ 12
        Forms of occurrence in coal........ 13
    Ultimate analysis........ 14
    Calorific value........ 14
      Direct determination in the bomb calorimeter........ 14
      Calculation of calorific value by Dulong's formulas........ 15
  Descriptions of samples........ 15
    Classification of coal........ 15
Tabulated analyses........ 16
  Alabama........ 17
    Jefferson County........ 17
    St. Clair County........ 18
    Shelby County........ 18
    Tuscaloosa County........ 19
  Alaska........ 19
    Alaska Peninsula........ 19
    Bering River........ 19
    Matanuska........ 22

Tabulated analyses—Continued.

Page.
Colorado........ 23
Adams County........ 23
Boulder County........ 24
Delta County........ 24
El Paso County........ 24
Fremont County........ 24
Garfield County........ 25
Gunnison County........ 25
Huerfano County........ 26
Jackson County........ 26
Jefferson County........ 27
La Plata County........ 27
Las Animas County........ 28
Mesa County........ 33
Moffat County........ 33
Montezuma County........ 33
Ouray County........ 35
Rio Blanco County........ 35
Idaho........ 35
Boise County........ 35
Cassia County........ 36
Fremont County........ 36
Illinois........ 36
Madison County........ 36
Montgomery County........ 37
Saline County........ 37
Vermilion County........ 37
Indiana........ 37
Sullivan County........ 37
Warrick County........ 37
Kansas........ 37
Crawford County........ 37
Leavenworth County........ 38
Kentucky........ 39
Letcher County........ 39
Muhlenberg County........ 40
Ohio County........ 41
Pike County........ 41
Missouri........ 41
Adair County........ 41
Audrain County........ 41
Barton County........ 42
Bates County........ 42
Boone County........ 44
Callaway County........ 45
Harrison County........ 45
Henry County........ 46
Linn County........ 48
Putnam County........ 49
Randolph County........ 50
Ray County........ 51
Vernon County........ 51

Tabulated analyses—Continued.

Page.
Montana 52
- Blaine County 52
- Carbon County 52
- Chouteau County 54
- Custer County 54
- Dawson County 54
- Fergus County 54
- Flathead County 55
- Missoula County 55
- Musselshell County 55
- Rosebud County 55
- Teton County 55
- Valley County 55

Nevada 57
- Esmeralda County 57

New Mexico 57
- Bernalillo County 57
- Colfax County 57
- Lincoln County 59
- McKinley County 59
- Santa Fe County 59

North Dakota 59
- Adams County 59
- Bowman County 59
- Morton County 60
- Ward County 60
- Williams County 60

Ohio 61
- Jefferson County 61
- Noble County 63

Oklahoma 64
- Haskell County 64
- Pittsburg County 64

Oregon 66
- Coos County 66
- Malheur County 67

Pennsylvania 67
- Allegheny County 67
- Bedford County 68
- Cambria County 69
- Center County 84
- Clearfield County 85
- Huntingdon County 90
- Indiana County 91
- Jefferson County 93
- Lackawanna County 93
- Luzerne County 93
- Somerset County 93
- Washington County 97
- Westmoreland County 99

South Dakota 100
- Harding County 100
- Perkins County 100

Tabulated analyses—Continued.

Page.
Tennessee.......... 101
Anderson County.......... 101
Bledsoe County.......... 101
Cumberland County.......... 101
Rhea County.......... 102
Utah.......... 103
Carbon County.......... 103
Emery County.......... 104
Sevier County.......... 104
Summit County.......... 105
Uinta County.......... 105
Wasatch County.......... 105
Virginia.......... 105
Dickenson County.......... 105
Henrico County.......... 106
Russell County.......... 106
Wise County.......... 106
Washington.......... 107
King County.......... 107
Kittitas County.......... 107
Lewis County.......... 108
Pierce County.......... 108
West Virginia.......... 110
Braxton County.......... 110
Brooke County.......... 111
Fayette County.......... 111
Greenbrier County.......... 114
McDowell County.......... 114
Marion County.......... 121
Marshall County.......... 122
Mercer County.......... 122
Monongalia County.......... 126
Preston County.......... 127
Raleigh County.......... 127
Randolph County.......... 132
Wyoming.......... 132
Converse County.......... 132
Crook County.......... 133
Fremont County.......... 133
Hot Springs County.......... 134
Johnson County.......... 137
Natrona County.......... 138
Park County.......... 138
Sheridan County.......... 139
Sweetwater County.......... 144
Uinta County.......... 145
Weston County.......... 146
Descriptions of samples.......... 147
Alabama.......... 147
Jefferson County.......... 147
St. Clair County.......... 148
Shelby County.......... 150
Tuscaloosa County.......... 150

Descriptions of samples—Continued.

Page.
Alaska 151
- Alaska Peninsula 151
- Bering River 151
- Matanuska 156

Colorado 163
- Adams County 163
- Boulder County 163
- Delta County 164
- El Paso County 165
- Fremont County 167
- Garfield County 168
- Gunnison County 169
- Huerfano County 170
- Jackson County 171
- Jefferson County 173
- La Plata County 174
- Las Animas County 176
- Mesa County 184
- Moffat County 185
- Montezuma County 187
- Ouray County 192
- Rio Blanco County 192

Idaho 194
- Boise County 194
- Cassia County 195
- Fremont County 195

Illinois 196
- Madison County 196
- Montgomery County 197
- Saline County 198
- Vermilion County 199

Indiana 199
- Sullivan County 199
- Warrick County 200

Kansas 200
- Crawford County 200
- Leavenworth County 202

Kentucky 203
- Letcher County 203
- Muhlenberg County 205
- Ohio County 207
- Pike County 207

Missouri 207
- Adair County 207
- Audrain County 208
- Barton County 208
- Bates County 209
- Boone County 211
- Callaway County 212
- Harrison County 212
- Henry County 213
- Linn County 217
- Putnam County 218

Descriptions of samples—Continued.

Missouri—Continued.

Page.

- Randolph County 219
- Ray County 220
- Vernon County 221

- Montana 221
  - Blaine County 221
  - Carbon County 222
  - Chouteau County 224
  - Custer County 225
  - Dawson County 226
  - Fergus County 226
  - Flathead County 227
  - Missoula County 227
  - Musselshell County 228
  - Rosebud County 228
  - Teton County 229
  - Valley County 230
- Nevada 234
  - Esmeralda County 234
- New Mexico 235
  - Bernalillo County 235
  - Colfax County 235
  - Lincoln County 239
  - McKinley County 240
  - Santa Fe County 240
- North Dakota 242
  - Adams County 242
  - Bowman County 242
  - Morton County 244
  - Ward County 244
  - Williams County 244
- Ohio 246
  - Jefferson County 246
  - Noble County 251
- Oklahoma 251
  - Haskell County 251
  - Pittsburg County 252
- Oregon 255
  - Coos County 255
  - Malheur County 257
- Pennsylvania 257
  - Allegheny County 257
  - Bedford County 260
  - Cambria County 261
  - Center County 286
  - Clearfield County 289
  - Huntingdon County 297
  - Indiana County 299
  - Jefferson County 302
  - Lackawanna County 303
  - Luzerne County 303
  - Somerset County 304
  - Washington County 311
  - Westmoreland County 314

Descriptions of samples—Continued.

Page.

- South Dakota........ 316
  - Harding County........ 316
  - Perkins County........ 317
- Tennessee........ 319
  - Anderson County........ 319
  - Bledsoe County........ 319
  - Cumberland County........ 321
  - Rhea County........ 322
- Utah........ 323
  - Carbon County........ 323
  - Emery County........ 326
  - Sevier County........ 328
  - Summit County........ 329
  - Uinta County........ 330
  - Wasatch County........ 331
- Virginia........ 332
  - Dickenson County........ 332
  - Henrico County........ 333
  - Russell County........ 334
  - Wise County........ 335
- Washington........ 336
  - King County........ 336
  - Kittitas County........ 337
  - Lewis County........ 339
  - Pierce County........ 341
- West Virginia........ 344
  - Braxton County........ 344
  - Brooke County........ 344
  - Fayette County........ 345
  - Greenbrier County........ 351
  - McDowell County........ 352
  - Marion County........ 365
  - Marshall County........ 367
  - Mercer County........ 368
  - Monongalia County........ 377
  - Preston County........ 377
  - Raleigh County........ 378
  - Randolph County........ 386
- Wyoming........ 387
  - Converse County........ 387
  - Crook County........ 390
  - Fremont County........ 391
  - Hot Springs County........ 394
  - Johnson County........ 397
  - Natrona County........ 400
  - Park County........ 400
  - Sheridan County........ 403
  - Sweetwater County........ 411
  - Uinta County........ 413
  - Weston County........ 415

Bibliography........ 417

Publications on fuel technology........ 425

Index........ 429

ILLUSTRATIONS.

Page.

FIGURE 1. Apparatus for determining volatile matter........................ 6

2. Electric furnace for volatile-matter determination................ 8

ANALYSES OF MINE AND CAR SAMPLES OF COAL COLLECTED IN THE FISCAL YEARS 1911 TO 1913.

By ARNO C. FIELDNER, HOWARD I. SMITH, ALBERT H. FAY, and SAMUEL SANFORD.

SAMPLING AND ANALYTICAL METHODS.

By ARNO C. FIELDNER.

INTRODUCTION.

In connection with investigations relating to fuels belonging to or for the use of the United States Government, the causes of accidents in coal mines, the geologic relations of coal beds, and the character of the coal and the value of the fuel in the public lands, many mine samples of coal are analyzed each year in the laboratories of the Bureau of Mines. The systematic collection and analysis of coal samples in connection with investigations of fuels was begun in 1904 at the Government fuel-testing plant at the Louisiana Purchase Exposition, and was under the direction of the United States Geological Survey for six years. Descriptions of the coal samples collected in connection with these investigations between the beginning of this work, July 1, 1904, and the transfer of the fuel-testing and mine-accident investigations to the Bureau of Mines, July 1, 1910, were compiled and published in Bureau of Mines Bulletin 22.[a]

The present bulletin presents analyses and descriptions of samples collected during the fiscal years 1911 to 1913. In order that the material in this bulletin may be used to supplement that presented in Bulletin 22, the same plan of geographical classification has been followed, the analyses and descriptions of the samples being grouped in alphabetical order according to the State, county, and town near which the mines or prospects sampled are situated.

---

[a] Lord, N. W., and others: Analyses of coals in the United States, with descriptions of mine and field samples collected between July 1, 1904, and June 30, 1910. Bull. 22, Bureau of Mines, 1912. 1,200 pp. (in two parts).

ACKNOWLEDGMENTS.

Special acknowledgment is due to G. O. Smith, Director of the United States Geological Survey, and to M. R. Campbell, geologist in charge of the economic geology of fuels, for furnishing field descriptions of those samples collected by the geologists of the survey, and for revising the nomenclature of coal beds and geologic formations.

The mine samples from Missouri were collected under the direction of H. A. Buehler, director of the Missouri Geological Survey.

The collection of samples by the fuel-inspection service of the Bureau of Mines was under the direction of G. S. Pope, engineer. Samples designated by the letter W preceding the laboratory number were analyzed in the Washington laboratory of the bureau under the direction of J. D. Davis, chemist.

The collection of mine samples and the gathering of mine data by the field engineers of the bureau were done under the direction of G. S. Rice, chief mining engineer of the bureau, who has also reviewed the descriptions and comments on the methods of field sampling. The descriptions of the mines and the sections of the coal beds were compiled by H. I. Smith and A. H. Fay, mining engineers, and Samuel Sanford, engineer. The chemical analyses were made under the direction of A. C. Fieldner, chemist, who was assisted by D. I. Brown, assistant chemist; C. K. Glycart, A. E. Hall, Harold Isenberg, W. A. Mueller, G. G. Oberfell, F. D. Osgood, G. E. Postma, W. A. Selvig, C. A. Taylor, G. G. Taylor, G. E. Webster, A. M. Wedd, and H. G. Woodward, junior chemists; W. E. Surbled, laboratory assistant; Max Hecht and Morris Block, laboratory helpers. The junior chemists and laboratory helpers were engaged on coal analyses for varying lengths of time, ranging from one month to two years. The computing and the tabulating of the analyses at the Pittsburgh laboratory were under the direction of Lauson Stone, engineer.

COLLECTION OF SAMPLES.

Samples designated by the letter A in the table of analyses were collected by representatives of the Bureau of Mines, in connection with the investigation of fuels belonging to, or for the use of, the Government; and the investigation of accidents in coal mines. Under this designation are also included a number of samples collected by the Missouri Geological Survey in cooperation with the Bureau of Mines.

The samples designated by the letter B in the table of analyses were collected by the United States Geological Survey in connection with the study of the geologic relations of coal beds and the classification of public lands.

METHOD OF MINE SAMPLING FOLLOWED BY BUREAU OF MINES.

The method of collecting mine samples that is practiced by the Bureau of Mines has been described in detail in a previous publication.[a] It involves selecting a representative face of the bed to be sampled; cleaning the face; making a cut across it from roof to floor, and rejecting or including impurities in this cut according to a definite plan as they are included or excluded in mining operations; reducing this gross sample, by crushing and quartering, to about 3 pounds; and immediately sealing the 3-pound sample in an air-tight container for shipment to the laboratory.

COLLECTION OF CAR SAMPLES.

The carload lots of coal shipped to Pittsburgh for test were sampled by taking definite quantities of coal at regular intervals from a car as it was unloaded, and by reducing to convenient size (about 50 pounds) the gross sample thus obtained.

METHOD OF SAMPLING FOLLOWED BY THE UNITED STATES GEOLOGICAL SURVEY.

In collecting mine samples the Geological Survey follows essentially the same method of sampling as that used by the Bureau of Mines. However, in sampling outcrops and prospect holes or country banks when mining is not in progress, the geologist can not imitate the miner in rejecting or including impurities in the sample, and hence the sample from the cut across the bed includes all partings or binders less than three-eighths of an inch thick and every concretion or "sulphur ball" having a maximum diameter of less than 2 inches and a thickness of less than one-half inch. All other impurities in the bed are excluded from the sample. Obviously an arbitrary and uniform system of rejecting impurities is necessary for sampling outcrops, prospects, and undeveloped mines.

RELATION OF MINE SAMPLES TO COMMERCIAL SHIPMENTS.

In making statements, on the basis of the analyses of mine samples, in regard to the quality of coal shipped from a mine due allowance must be made for the larger proportion of impurities that may be included in the commercial operation of the mine. It is difficult to take a mine sample in which impurities are rejected in exactly the same manner as is done by the miner. The practice of different miners will vary, especially if rigid inspection at the tipple is not enforced. In some mines, for instance, where the coal bed has friable partings or has a soft, flaky roof or floor, the inclusion of some foreign matter is unavoidable. Hence the analysis of the mine sample usually indicates a better grade of coal, as regards ash content and heating value, than the actual commercial shipments, and for this reason the mine sample should be considered as representing the coal that can only be produced under the most favorable conditions of mining and preparation.

---

[a] Holmes, J. A., The sampling of coal in the mine: Technical Paper 1, Bureau of Mines, 1911, 18 pp.

In commercial shipments that are sampled at their destination the moisture content may be either more or less than that in the mine samples, the relative proportions depending on the amount of bed moisture, the size of the coal, and the weather conditions during transit.

Coals containing 5 per cent or more of moisture tend to lose moisture while in transit. Slack coal usually contains more moisture than the mine sample. Low-moisture coals shipped in open cars may gain or lose moisture, depending on weather conditions.[a]

The calorific value, referred to moisture-free and ash-free coal, of samples taken from shipments at destination, tends to be slightly lower than that of the fresh mine samples from the same mine. The deterioration is caused mainly by the freshly exposed surfaces of coal absorbing oxygen from the air. The rate of deterioration varies with the different types of coal and depends on a number of factors, chief of which are: (1) Size of coal, (2) proportion of surface exposed to circulating air, (3) duration of exposure, (4) temperature and humidity.

It is therefore difficult to assign any definite values for deterioration of coal while in transit.[b] A number of mine and car samples tested by the United States Geological Survey and the Bureau of Mines showed the following average losses:

Average loss in moisture-free and ash-free calorific value of car sample as compared with that of mine sample.

Kind of coal.	Per cent.
Semibituminous, New River and Pocahontas	0.1
Bituminous, Appalachian field	.3
Bituminous, Illinois, Indiana, and Missouri	.8
Subbituminous and lignite	1.3

---

[a] For a comparison of the moisture, ash, and sulphur contents of mine and car samples tested at the United States fuel-testing plant, St. Louis, Mo., see Burrows, J. S., The importance of uniform and systematic coal-mine sampling: U. S. Geol. Survey Bull. 316, 1907, pp. 490-560. For a discussion of moisture in coal deliveries, see Pope, G. S., Sampling coal deliveries: Bull. 63, Bureau of Mines, 1913, p. 12.

[b] For data on deterioration of coal see Porter, H. C., and Ovitz, F. K., Deterioration and spontaneous combustion of coal in storage, a preliminary report: Tech. Paper 16, Bureau of Mines, 1912, 14 pp.; The escape of gas from coal: Tech. Paper 2, Bureau of Mines, 1911, 14 pp., 1 fig.; Parr, S. W., and Wheeler, W. F., The weathering of coal: University of Illinois Eng. Exp. Station Bull. 38, 1909.

ANALYTICAL METHODS.

The methods of analysis and the details of apparatus used by the Bureau of Mines in analyzing coal are fully described in Bulletin 22 [a] and Technical Paper 8 [b] of the Bureau of Mines. They are briefly summarized here, certain changes in minor details, which are fully discussed in Technical Paper 76,[c] being described.

PREPARATION OF LABORATORY SAMPLES.

Immediately after the sealed 3-pound can in which the sample is received at the laboratory has been opened, the contents are transferred to a weighed sheet-metal pan, spread out to a depth of 1 inch, and at once weighed. The pan containing the sample is placed in a large drying oven in which a temperature of 30° to 35° C. is maintained. Through this oven a current of warm air is made to flow by means of an ordinary desk fan mounted on top of the oven, and the sample is dried until the loss in weight between two successive weighings, made 6 to 12 hours apart, does not exceed 0.5 per cent. The total loss of weight is reported as "air-drying loss."

Immediately after the last weighing has been made the entire sample is quickly pulverized to 10-mesh size by being passed through a roll crusher. After having been mixed, the 10-mesh material is reduced with a riffle sampler to 500 grams. This 500-gram part is at once transferred to the porcelain jar of an Abbe ball mill, which is sealed air-tight and rotated at the rate of 60 revolutions per minute until the coal is pulverized to 60-mesh size.

This 60-mesh coal is emptied on a one-half-inch screen, which is vigorously shaken to detach the coal from the pebbles. The sample (approximately 500 grams) is then reduced to the final laboratory sample of approximately 60 grams by successive halvings with a small riffle sampler. The final sample is put through the 60-mesh sieve and at once transferred to a 4-ounce wide-mouthed bottle, which is securely closed with a well-fitting rubber stopper. Any particles of coarse material remaining on the sieve are carefully rubbed down to 60-mesh size on a bucking board and are thoroughly mixed with the sample in the bottle.

This air-dried sample is used in all analytical determinations.

---

[a] Lord, N. W., and others, Analyses of coals in the United States, with descriptions of mine and field samples collected between July 1, 1904, and June 30, 1910: Bull. 22, Bureau of Mines, 1913, pp. 10-26.

[b] Stanton, F. M., and Fieldner, A. C., Methods of analyzing coal and coke, Tech. Paper 8, Bureau of Mines, 1913, 42 pp.

[c] Fieldner, A. C., Notes on the sampling and analysis of coal: Tech. Paper 76, Bureau of Mines, 1914, pp. 14-58.

DETERMINATION OF MOISTURE.

The residual moisture in the air-dried sample is determined by heating 1 gram in a shallow porcelain capsule, seven-eighths of an inch deep and 1¾ inches in diameter, for one hour at 105° C. in a constant-temperature oven through which a current of dry preheated air is rapidly passing. The air is dried by being passed through concentrated sulphuric acid. The covered capsule is cooled in a desiccator over sulphuric acid and then weighed. The loss in weight is called "moisture at 105°" in the air-dried coal.

ASH DETERMINATION.

The same sample is used for determining ash as was previously used for determining moisture. A porcelain capsule containing the sample is placed in a cool muffle and the temperature is gradually raised to approximately 750° C. The ignition in the muffle is continued, with occasional stirring of the ash, until all particles of carbon have disappeared. After the capsule containing the ash has been cooled in a desiccator it is weighed and ignition is repeated until constant weight (0.0005 gram or less) has been attained.

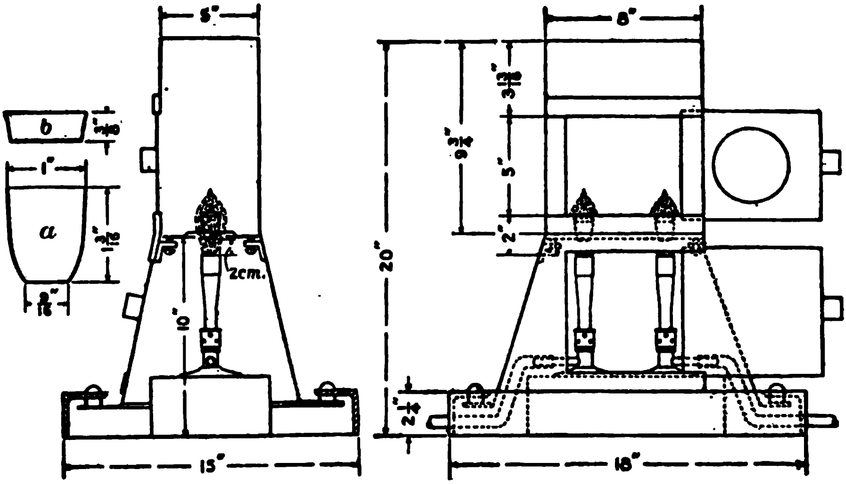


FIGURE 1.—Apparatus for determining volatile matter.

The ash content as determined by this method represents the ignited mineral residue or "uncorrected ash."

DETERMINATION OF VOLATILE MATTER.

APPARATUS.

A 1-gram sample of the fine (60-mesh) coal is weighed into a bright, well-burnished, 10-gram (10 c. c.) platinum crucible (*a*, fig. 1), with a close-fitting capsule cover, *b*. The crucible and contents are heated to a temperature of 950° C. upon a platinum or nichrome triangle for seven minutes in the full flame of a No. 3 Meker burner. The gas orifice of the burner is adjusted to give a free-burning flame from 16 to 18 cm. high. The crucible should be so placed in the triangle that its bottom is 2 cm. above the top of the burner. To protect the crucible from the effects of drafts it is put in a sheet-iron chimney of special design. The maximum temperature, as measured by a thermocouple whose hot junction is buried in the coal and in contact with the inside surface of the bottom, should be 950° C. After being heated exactly seven minutes, the crucible is cooled and weighed. The loss in weight minus the weight of moisture determined at 105° C. times 100 equals the percentage of volatile matter.

MODIFIED METHOD FOR LIGNITES AND SUBBITUMINOUS COALS.

Lignites and coals high in moisture are heated at a low temperature until all the moisture is driven out in order to avoid mechanical losses from material thrown out of the crucible by the rapid escape of steam and volatile matter.[a] This preliminary heating for four to six minutes is followed by the usual 7-minute application of the full flame.

It should be clearly understood that the volatile matter does not represent any definite compound in the coal. The method of determination is wholly conventional, and any variation in temperature or rate of heating will change the amount of volatile matter determined.

USE OF THE ELECTRIC FURNACE.

Since February 26, 1913, all volatile-matter determinations at the bureau's laboratory in Pittsburgh have been made in specially designed electric furnaces of the vertical type (fig. 2). Two of these furnaces are connected in series and are controlled by a single rheostat. A current of 8 to 9 amperes is required to maintain the temperature of each furnace at 950° C. Under these conditions the drop in potential across the two furnaces is 60 volts. The life of the heating element under daily operation has been six to eight months. Each furnace contains a platinum platinum-rhodium thermocouple that is connected to a millivoltmeter through a double-pole, double-throw switch. The position of the hot junction in each furnace is so adjusted that the direct reading of the temperature scale of the millivoltmeter is the same as the maximum temperature attained inside the crucible as determined by another standardized couple whose hot junction is in contact with the bottom of the interior of the

---

[a] Lord, N. W.: Experimental work conducted in the chemical laboratory of the United States fuel-testing plant at St. Louis, Mo. U. S. Geol. Survey Bull. 323 (reprinted as Bull. 28, Bureau of Mines), pp. 6-7.

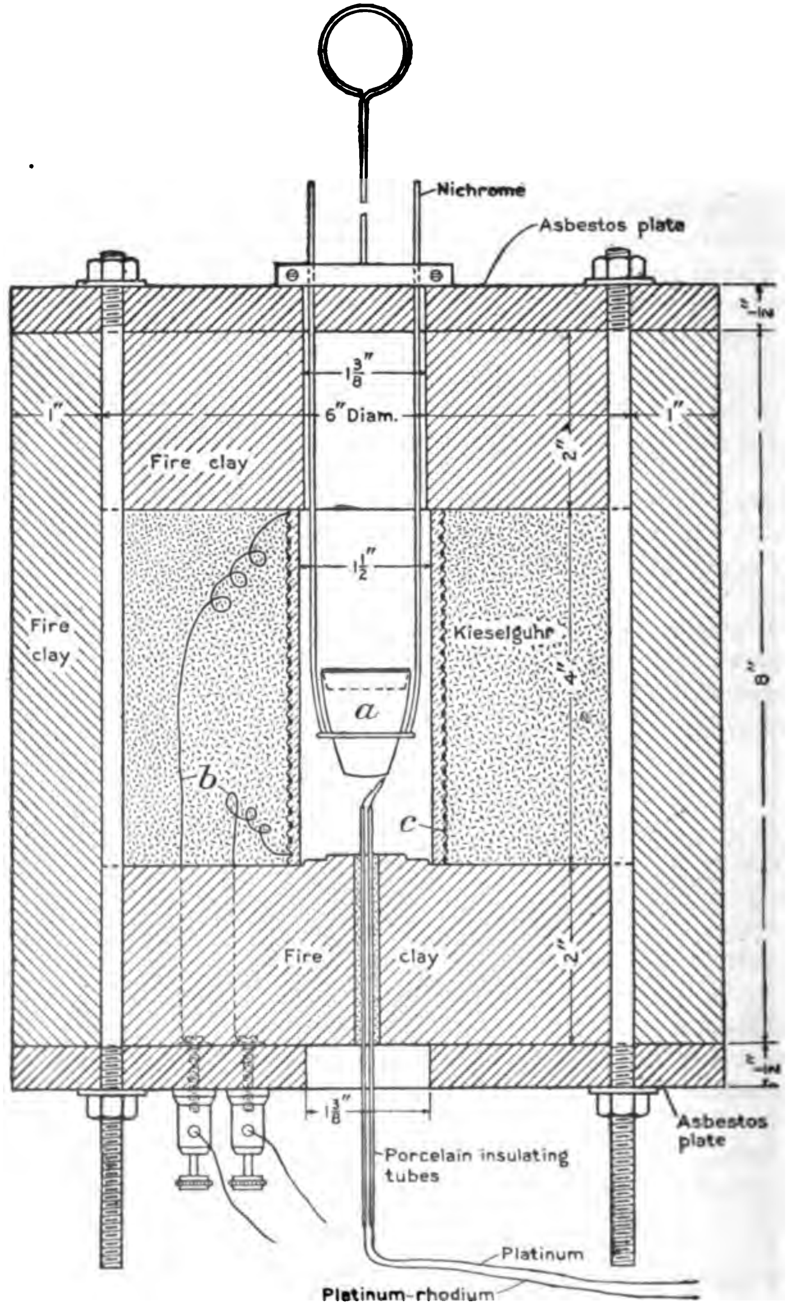


FIGURE 2.—Electric furnace for volatile-matter determination.

crucible. In making this comparison a nickel cover perforated for admitting the thermocouple leads is substituted for the usual platinum cover of the crucible. To avoid possible contamination of the thermocouple, 1 gram of ignited silica or alumina is used instead of coal.

DETERMINATION OF FIXED CARBON.

The fixed carbon content of the sample is determined by calculation—by subtracting the sum of the percentages of moisture, ash, and volatile matter from 100.

SULPHUR DETERMINATION.

Sulphur is determined by the Eschka method. A 1.3737-gram part of the air-dried coal is mixed with 6 grams of Eschka mixture in a No. 1 porcelain crucible and gradually heated in a muffle, with free access of air, until all the carbon has been consumed. The sulphur is extracted with hot water, completely oxidized to sulphate with bromine water, and precipitated and weighed as barium sulphate.

DETERMINATION OF CARBON AND HYDROGEN.

Carbon and hydrogen are determined by the usual method of combustion in a current of oxygen. A 0.2-gram part of the air-dried coal is burned in a 25-burner combustion furnace of the Glazer type or in an electrically heated furnace of the Heraeus type. Complete oxidation is insured by passing the products of combustion over red-hot copper oxide. A layer of lead chromate, following the copper oxide, removes the sulphur. The water and carbon dioxide are absorbed and weighed in calcium chloride and potassium hydroxide solution respectively. No correction is made for carbon or hydrogen from inorganic matter in the coal.

NITROGEN DETERMINATION.

Nitrogen is determined by the Kjeldahl-Gunning method. One gram of the air-dried coal is digested with 30 c. c. of concentrated sulphuric acid, 0.5 gram of metallic mercury, and 5 grams of potassium sulphate, until the carbon has been completely oxidized and all the nitrogen has been converted to ammonium sulphate. After dilution with water and precipitation of the mercury by the addition of potassium sulphide, an excess of sodium hydroxide is added and the ammonia determined by distillation.

DETERMINATION OF CALIFORIC VALUE.

The heat of combustion is determined with the bomb calorimeter. One gram of the air-dried coal is completely burned in compressed oxygen gas and the total heat evolved is absorbed in a weighed quantity of water in which the bomb is immersed. The rise in tem-

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ALABAMA—Continued.																
ST. CLAIR COUNTY.																
Coal City; Coal Branch mine, Coal City bed (first left room off entry 26, 3,000 feet north of slope mouth, 5-foot bed, 4-foot 10-inch cut).	149	12440	B	1	2.79	32.92	60.28	4.01	1.10	......	......	......	......	1.8	8,053	14,495
				2	......	33.86	62.01	4.13	1.13	......	......	......	......	......	8,284	14,911
				3	......	35.32	64.68	......	1.18	......	......	......	......	......	8,641	15,554
Same (end of entry 34, 2,800 feet north of slope mouth, 3-foot 10-inch cut).	149	12441	B	1	1.97	34.32	58.21	5.50	1.30	......	......	......	......	1.2	8,002	14,404
				2	......	35.01	59.38	5.61	1.33	......	......	......	......	......	8,163	14,693
				3	......	37.09	62.91	......	1.41	......	......	......	......	......	8,648	15,566
Same (end of room 32, 3,000 feet northeast of slope mouth, 2-foot 10-inch cut).	149	12442	B	1	2.41	33.72	60.65	3.22	.81	......	......	......	......	1.4	8,214	14,785
				2	......	34.55	62.15	3.30	.83	......	......	......	......	......	8,417	15,151
				3	......	35.73	64.27	......	.86	......	......	......	......	......	8,704	15,667
Same (composite of samples 12440, 12441, and 12442).	149	12443	B	1	2.38	33.31	60.00	4.31	1.07	5.27	81.85	1.46	6.04	1.5	8,138	14,648
				2	......	34.12	61.46	4.42	1.10	5.13	83.85	1.50	4.00	......	8,337	15,007
				3	......	35.70	64.30	......	1.15	5.37	87.72	1.57	4.19	......	8,722	15,700
Coal City; Vulcan No. 4 mine, Broken Arrow bed (room 21, off left heading 2, 750 feet southeast of mine mouth, 4-foot 1½-inch bed, 3-foot 3½-inch cut).	149	12436	B	1	3.76	29.07	58.67	8.50	1.46	......	......	......	......	2.9	......	......
				2	......	30.21	60.96	8.83	1.52	......	......	......	......	......	......	......
				3	......	33.14	66.86	......	1.67	......	......	......	......	......	......	......
Same (in mine, 1,100 feet east of mine mouth, 4-foot 9-inch bed, 3-foot 8-inch cut).	149	12437	B	1	3.54	29.04	59.20	8.22	1.36	......	......	......	......	2.7	......	......
				2	......	30.11	61.37	8.52	1.41	......	......	......	......	......	......	......
				3	......	32.91	67.09	......	1.54	......	......	......	......	......	......	......
Same (room 15, left heading 2, 600 feet south of mine mouth, 3-foot 5-inch cut).	149	12438	B	1	4.42	27.72	56.57	11.29	1.43	......	......	......	......	3.7	......	......
				2	......	29.00	59.19	11.81	1.50	......	......	......	......	......	......	......
				3	......	32.88	67.12	......	1.70	......	......	......	......	......	......	......
Same (composite of samples 12436, 12437, and 12438).	149	12439	B	1	3.94	28.14	58.59	9.33	1.46	5.10	75.71	1.32	7.08	3.1	7,498	13,496
				2	......	29.29	61.00	9.71	1.52	4.85	78.81	1.37	3.74	......	7,806	14,049
				3	......	32.44	67.56	......	1.68	5.37	87.28	1.52	4.15	......	8,644	15,559
SHELBY COUNTY.																
Straven; sec. 7, T. 21 S., R. 3 W.; Straven mine, Upper Straven bed (near end of slope, 2,000 feet north of slope mouth; 4-foot 10½-inch bed, 3 foot ½-inch cut).	150	14391	B	1	3.06	35.64	53.33	7.97	.59	......	......	......	......	1.0	7,318	13,172
				2	......	36.77	55.01	8.22	.61	......	......	......	......	......	7,549	13,588
				3	......	40.06	59.94	......	.66	......	......	......	......	......	8,225	14,580

(1) Water or moisture; (2) mineral impurities that remain in a somewhat altered condition as ash when the coal is burned; (3) organic or combustible matter, which is approximately represented by the volatile matter and fixed carbon.

MOISTURE CONTENT.

The moisture in coal consists of (1) extraneous moisture, which comes from external sources, such as underground waters trickling over the face of the coal bed, through the coal bed, and, in places going to the dip, from the coal shot down lying in water, condensation from saturated mine air, or, as regards car samples, from atmospheric precipitation or from water used for washing the coal, and (2) inherent moisture, which is one of the products of the original vegetable matter from which coal is derived.

Analysis does not differentiate between extraneous and inherent moisture, because in air-drying coal not only is the extraneous or superficial moisture removed but also more or less of the inherent moisture, the amount depending on the fineness of the coal and the humidity of the air. The percentage loss of weight on air drying should be regarded merely as an indication of the relative tendency of different coals to lose moisture, after removal from the mine, on exposure to comparatively dry atmospheres.

The loss of weight on air drying at 30–35° C., combined with the loss of weight occurring when the air-dried sample is heated in a current of dry air at a temperature of 105° C., is considered equal to the total moisture in the coal as received at the laboratory.

ASH.

Ash is the incombustible residue left from complete combustion of the coal. It is derived from the inorganic matter in the coal, and is composed largely of compounds of silica, alumina, lime, and iron, together with smaller quantities of magnesia, titanium, and alkali compounds. The silica, alumina, and titanic oxide are derived from sand, clay, shale, and "slate"; the iron oxide mainly from iron pyrite; and the lime and magnesia from their corresponding carbonates and sulphates.

The ash-forming constituents consist of (1) "inherent" or "intrinsic" impurities that are present in an intimate mixture with the coal substance, and are derived either from the original vegetable material or from external sources during the accumulation of coal-forming plant remains; (2) impurities formed either during the laying down of the coal bed or subsequently, which occur in the form of partings, "veins," and nodules of clay, shale, pyrite, and calcite; and (3) impurities that become mechanically mixed with the coal in the process of mining, such as fragments of roof and floor.

INHERENT IMPURITIES.

The percentage of ash derived from the intimately mixed impurities may be determined by selecting a sample of clean lumps of homogeneous coal, or, better, by placing the coarsely crushed coal in a solution of calcium or zinc chloride with a specific gravity of 1.35. The coal will float and the heavier extraneous impurities will sink. In this way a sample of clean coal may be prepared for analysis. In some samples the percentage of "intrinsic" ash is so low that the ash must have come exclusively from the original coal-forming vegetation. Certain coals have deposited in their minute joints or cleavage planes thin flakes of calcite, gypsum, silica, or clay, and some have veinlets of pyrite. These impurities are not intimately mixed with the coal substance, but can not be separated from the coal by any commercial methods of preparation. In some coals, also, microscopic crystals of pyrite are so distributed that washing does not appreciably lower the sulphur content.

EXTRANEOUS IMPURITIES.

The percentage of ash derived from extraneous impurities varies considerably, depending on the number and size of the partings in the seam, the possibility of separating them from the coal, and the care with which the coal is mined. Such impurities of this character, when in the form of "slate" or bone, may be removed to some degree by suitable methods of washing, picking, or screening. The possibility of improving the quality of coal by washing may be determined by the laboratory float-and-sink test already described.

Coal ash, as determined, usually weighs less than the organic matter from which it is produced because of the loss of volatile constituents during ignition. Shale and clay lose their water of hydration; the carbonates are more or less decomposed, giving off carbon dioxide, and the iron pyrite is changed to ferric oxide, giving off sulphur dioxide, either to the atmosphere or to the free calcium oxide that has been formed from the carbonate. In coals containing calcium carbonate a large proportion of the sulphur may be retained in the ash as calcium sulphate.

VOLATILE MATTER AND FIXED CARBON.

The volatile matter and fixed carbon represent approximately the relative proportions of gaseous and solid combustible matter that are obtained from coal by heating it in a closed vessel. The volatile matter consists chiefly of the combustible gases hydrogen, carbon monoxide, and methane and other hydrocarbons, and some noncombustible gases, as carbon dioxide and water vapor. The volatile matter does not include the water that can be removed from the coal by heating it at 105° C.

From the standpoint of the analyst, 950° to 1,000° C. appears to be the best temperature for the determination of volatile matter, as most duplicate determinations made within those limits agree within 0.5 per cent.

The residue of coke left in the crucible after the ash has been deducted is reported as "fixed carbon." The fixed carbon does not represent the total carbon in the coal, for a considerable part of the carbon is expelled as volatile matter, being in combination with hydrogen as hydrocarbon or with oxygen as carbon monoxide and carbon dioxide. Furthermore, fixed carbon is not pure carbon. The carbonized residue contains, in addition to the ash-forming constituents, several tenths per cent of hydrogen and oxygen, from 0.4 to 1.0 per cent nitrogen, and approximately half the sulphur that was in the coal. The terms "volatile matter" or "volatile combustible matter" and "fixed carbon" do not represent definite compounds that existed in the coal before heating. The method of determination is arbitrary, and results are comparable only when the temperature and rate of heating are the same. In general the sum of the fixed carbon and ash may be taken as representing the relative amount of coke yield from coking coals. However, the conditions under which the laboratory determination is made are so different from the conditions in the commercial manufacture of coke or gas that no close agreement can be expected. The slow rate of heating in the industrial processes yields several per cent more coke than is obtained in the laboratory determination.

SULPHUR.

In the proximate analysis of coal the sulphur is included in the volatile matter, fixed carbon, and ash. If the ash contains no lime or alkali oxides, all the sulphur is distributed between the volatile matter and fixed carbon, approximately half the sulphur being retained by the fixed carbon and the remainder escaping with the volatile matter.

FORMS OF OCCURRENCE IN COAL.

Sulphur occurs in coal (1) as pyrite or marcasite, (2) as sulphate of iron, lime, and alumina, and (3) in combination with the coal substance as organic compounds.

In some coal beds balls, lenses, and bands of pyrite are easily distinguishable in the face of the bed, and may be largely removed by breaking up the lumps of coal containing them and by suitable washing or picking. In other beds the pyrite is disseminated throughout the lumps of coal in veinlets or in such small particles that it is not practicable to separate them from the lump coal or even to remove them from the screenings by washing.

Sulphur combined as sulphates of iron, lime, and alumina may be found in weathered coal. On exposure to air pyrite and marcasite tend to absorb oxygen and form iron sulphate. Sulphur combined as sulphate has no heating value.

Next to pyritic sulphur the most prominent form of sulphur in coal is that which occurs in some organic combination with the coal substance. There is no direct method of quantitatively determining the relative amounts of pyritic and "organic" sulphur. However, as regards many coals, if all the sulphate sulphur and an amount of sulphur sufficient to form pyrite equivalent to all the iron in the coal be deducted from the total sulphur, there yet remains a considerable amount of sulphur.

ULTIMATE ANALYSIS.

In the ultimate analysis the composition of coal is expressed in percentages of ash, sulphur, carbon, hydrogen, nitrogen, and oxygen. The sum of these constituents is taken as equal to 100 per cent. As there is no simple direct method for the determination of oxygen, it is estimated by subtracting the sum of the other five constituents from 100. This method throws the summation of all the errors incurred in the other determinations upon the oxygen.

The determination of carbon, hydrogen, and nitrogen, although requiring experience and a considerable degree of skill on the part of the chemist, is not subject to the arbitrary conditions that must be maintained in the proximate analysis. As the chemist is dealing with definite chemical elements, he should be able to make duplicate determinations, agreeing within the following limits: Carbon, 0.3 per cent; hydrogen, 0.07 per cent; nitrogen, 0.05 per cent.

CALIFORIC VALUE.

DIRECT DETERMINATION IN THE BOMB CALORIMETER.

The most accurate method of determining the total heating value is by combustion in a bomb calorimeter. The instrument should be carefully standardized by burning substances of known calorific value, such as the standard samples of cane sugar, naphthalene, and benzoic acid, that are now being furnished by the Bureau of Standards. The standardization should be conducted under exactly the same conditions and with the same thermometer that is used in the tests. The use of calibrated thermometers is essential. In carefully conducted calorimetric work the probable error should not exceed 0.3 per cent, which corresponds to about 50 B. t. u. in a high-grade coal.

This degree of accuracy is higher than can be obtained in the usual methods of sampling, the error introduced by which oftentimes increases the total error to 100 B. t. u.

CALCULATION OF CALORIFIC VALUE BY DULONG'S FORMULAS.

Before the bomb calorimeter came into general use the heating value of a coal was frequently calculated from the ultimate analysis by one of Dulong's formulas. These formulas, which are occasionally used in the bureau's work to verify results with the bomb calorimeter, are as follows:

(1) Calorific value in calories per gram $= 8080C + 34460(H - \frac{O}{8}) + 2250S$.

(2) Calorific value in B. t. u. per pound $= 14544C + 62028(H - \frac{O}{8}) + 4050S$.

There is fairly close agreement between the calorific values calculated by Dulong's formula and those determined by the calorimeter. In coals of higher rank than subbituminous the agreement is usually within 1.5 per cent.

DESCRIPTIONS OF SAMPLES.

The samples of coal and the mines from which they were taken are described in the same general manner as the corresponding information was presented in Bulletin 22. The descriptions have been compiled from published reports or from the note books of the engineers or geologists who collected the samples and necessarily vary in completeness. The purpose of the descriptions is to present such information as bears on the significance of the analyses and to give supplementary details, such as methods of mining and clearing coal, that may be of assistance to Government engineers or purchasing agents and to other persons in preparing specifications and awarding contracts for fuel.

The names of the coal beds, geologic formations, mining districts, and coal fields are those used by the United States Geological Survey. In the descriptions of the sections of coal beds, the word "shale" has been substituted for the "slate" of collectors and "bony coal" or "bone" for "bone coal."

CLASSIFICATION OF COAL.

The usage of the Survey has been followed also in the classification of the coals. The following statement on coal classification is made by Campbell[a] in a recent report.

---

[a] Campbell, M. R., Analyses of coal samples from various fields in the United States: U. S. Geol. Survey Bull. 541, 1914.

The classification of coal into various grades, such as bituminous, semibituminous, and lignite, is arbitrary and not at all satisfactory, but it is in common use in the United States, and it seems desirable to give the class for each sample, because from the analysis one could not always determine this important point. The classes generally used in the United States are as follows: Anthracite, semianthracite, semibituminous, bituminous, subbituminous, and lignite.

Anthracite.—Anthracite coal is generally well known, but in a systematic classification it is generally defined as a hard coal having a fuel ratio (fixed carbon divided by volatile matter) of not less than 10. Most of this coal comes from the anthracite fields of eastern Pennsylvania, but small areas are known in some of the Western States.

Semianthracite.—Semianthracite coal has a fuel ratio ranging from 6 or 7 to 10. There is only a small amount of this coal in the United States.

Semibituminous.—Semibituminous coal is of great commercial importance, but is not widely distributed. Its fuel ratio ranges from 3 to 6 or 7. It is the best steam coal in the country, and some of it can be utilized in the manufacture of coke. The centers of production are the Pocahontas and New River fields of Virginia and West Virginia, Georges Creek field of Maryland, Windber field of Pennsylvania, and the western end of the Arkansas field in the vicinity of Fort Smith. Though small areas containing this grade of coal have been found in Washington and Colorado, the amount of such coal in these fields is small.

Bituminous.—Bituminous coal is the most important grade in the country and includes most of the coals east of the Rocky Mountains. In the Western States there are large areas of bituminous coal, such as the Trinidad-Raton field of Colorado and New Mexico; the Grand Hogback field of Colorado; the Book Cliffs field of Utah; the Rock Springs, Kemmerer, and Black Hills fields of Wyoming; the Great Falls field of Montana; and many districts of Washington. This grade furnishes most of the coking coal of the country, and it is largely sold for steam raising and for domestic use.

Subbituminous.—The term "subbituminous" has been adopted by the United States Geological Survey for what has generally been called "black lignite." The latter term is objectionable, for the reason that the coal is not lignitic in the sense of being woody, and the use of the term seems to imply that the coal is little better than the brown, woody lignite of North Dakota, whereas many of the coals of this class closely approach the lowest grade of bituminous coal. In fact, it is extremely difficult to separate this class from the one below and the one above. It is generally distinguished from lignite by its color and freedom from apparent woody texture and from bituminous coal by the slacking it undergoes when exposed to the weather. As the latter is an important difference in commercial use, it has been adopted by the Geological Survey as the criterion for the separation of subbituminous and bituminous coals.

Subbituminous coal is found in most of the western fields, being well known in the field about Boulder and Denver and in North Park, Colo.; Gallup, N. Mex.; Hanna, Douglas, Sheridan, and the Bighorn Basin, Wyo.; Red Lodge and Musselshell, Mont., and in many of the districts of Washington and Oregon.

Lignite.—As used by the Geological Survey the term "lignite" is restricted to the coals that are distinctly brown and generally woody. They are intermediate in quality between peat and subbituminous coal. Lignite is abundant in the North in eastern Montana and North Dakota and in the northwest corner of South Dakota. In the South it is present in all of the Gulf States, but it has been developed commercially only in Texas.

TABULATED ANALYSES.

On the following pages are given the analyses of the samples of coal collected during the period covered by this report.

In the first column of the table, locations of samples are, for brevity, not worded as in the detailed descriptions (pp. 147–405). The word "cut" denotes thickness of coal sampled.

Table of chemical analyses.

Locality, bed, etc.	Mine notes[a] (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.[b]	Kind.[c]	Condition.[d]	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ALABAMA.																
JEFFERSON COUNTY.																
Littleton, near, 20 miles northwest of Birmingham; Banner mine, Big or Mary Lee bed (rib near mouth, room 4, right entry 5, 2,000 feet east of shaft No. 1, 8-foot 7½-inch bed, 6-foot 11½-inch cut).	147	12083	A	1	2.48	26.77	59.40	11.35	0.86	......	......	......	......	1.4	......	......
				2	......	27.45	60.91	11.64	.88	......	......	......	......	......	......	......
				3	......	31.07	68.93	......	1.00	......	......	......	......	......	......	......
Same (rib near mouth of room 2, left entry 8, 2,400 feet east of shaft No 1, 10-foot 4-inch bed, 7-foot 6-inch cut).	147	12084	A	1	2.29	26.73	59.84	11.14	.74	......	......	......	......	1.3	......	......
				2	......	27.36	61.24	11.40	.76	......	......	......	......	......	......	......
				3	......	30.88	69.12	......	.86	......	......	......	......	......	......	......
Same (right rib of main slope at mouth of left entry 9, 2,700 feet east of shaft No. 1, 10-foot bed, 7-foot 4-inch cut).	147	12085	A	1	2.42	26.89	60.04	10.65	.87	......	......	......	......	1.5	......	......
				2	......	27.56	61.53	10.91	.89	......	......	......	......	......	......	......
				3	......	30.94	69.06	......	1.00	......	......	......	......	......	......	......
Same (composite of samples 12083, 12084, and 12085).	147	12086	A	1	2.53	26.94	59.48	11.05	.79	4.80	74.44	1.59	7.33	1.4	7,381	13,286
				2	......	27.64	61.02	11.34	.81	4.64	76.38	1.63	5.20	......	7,573	13,631
				3	......	31.18	68.82	......	.91	5.23	86.15	1.84	5.87	......	8,542	15,376
Morris, 4 miles east of; Indlo mine, Jefferson bed (face of room 7, off left south entry 5, 2,000 feet southeast of shaft, 4-foot 5-inch bed, 2-foot 7-inch cut).	148	16683	A	1	1.96	30.97	59.03	8.04	3.26	......	......	......	......	1.1	7,705	13,869
				2	......	31.59	60.21	8.20	3.33	......	......	......	......	......	7,859	14,146
				3	......	34.41	65.59	......	3.63	......	......	......	......	......	8,561	15,410
Same (face of room 4, off right north entry 7, 2,500 feet northeast of shaft, 4-foot 8-inch bed, 2-foot 9-inch cut).	148	16684	A	1	2.23	30.96	59.91	6.90	2.56	......	......	......	......	1.4	7,828	14,090
				2	......	31.67	61.27	7.06	2.62	......	......	......	......	......	8,006	14,411
				3	......	34.08	65.92	......	2.82	......	......	......	......	......	8,614	15,506
Same (entrance to room 4, off right south entry 6, 4-foot ½-inch bed, 2-foot 4½-inch cut).	148	16685	A	1	1.95	30.88	59.40	7.77	2.45	......	......	......	......	1.1	7,736	13,925
				2	......	31.49	60.59	7.92	2.50	......	......	......	......	......	7,890	14,202
				3	......	34.20	65.80	......	2.72	......	......	......	......	......	8,569	15,424
Same (in main south aircourse, at left south entry 6, 4-foot 1-inch bed, 2-foot 7-inch cut).	148	16686	A	1	1.83	30.54	61.11	6.52	2.68	......	......	......	......	.9	7,873	14,171
				2	......	31.11	62.25	6.64	2.73	......	......	......	......	......	8,019	14,434
				3	......	33.32	66.68	......	2.92	......	......	......	......	......	8,589	15,460
Same (composite of samples 16683, 16684, 16685, and 16686).	148	16687	A	1	1.95	30.66	60.04	7.35	2.75	4.93	77.71	1.70	5.56	1.1	7,757	13,963
				2	......	31.27	61.23	7.50	2.80	4.80	79.26	1.73	3.91	......	7,911	14,240
				3	......	33.81	66.19	......	3.03	5.19	85.69	1.87	4.22	......	8,553	15,396

[a] Figures in column No. 2 refer to page of this bulletin where may be found the description of the section in the mine where the sample was taken.

[b] Laboratory numbers with a prefix "W" represent samples analyzed in the Washington laboratory of the bureau; all others were analyzed at the Pittsburgh laboratory. An asterisk preceding the laboratory number indicates that the volatile matter was determined by the modified method, see page 7.

[c] The kind of sample is denoted by letter, as follows: A=mine sample collected by an inspector of the Bureau of Mines; B=mine sample collected by a geologist of the United States Geological Survey; C=car sample taken at the fuel-testing plant.

[d] The form of analysis is denoted by number, as follows: 1=sample as received; 2=dried at a temperature of 105° C.: 3=moisture and ash free.

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
COLORADO—Continued.																
BOULDER COUNTY.																
Lafayette; Simpson mine, Simpson bed (room 1, off entry 125; 11-foot bed, 6-foot 10-inch cut).	163	*15165	A	1	20.71	31.82	43.98	3.49	0.45	6.04	57.80	1.20	31.02	10.3	5,523	9,941
				2	......	40.13	55.47	4.40	.57	4.72	72.90	1.51	15.90	......	6,966	12,539
				3	......	41.98	58.02	......	.60	4.94	76.25	1.58	16.63	......	7,286	13,115
DELTA COUNTY.																
Bowie, 1 mile from; T. 13 S., R. 91 W.; King mine, King bed (face of room 5, off left entry 3, 3,600 feet from mine mouth; 10-foot 2-inch bed and cut).	164	*15213	A	1	5.08	35.93	54.35	4.64	.60	......	......	......	......	2.3	......	......
				2	......	37.85	57.26	4.89	.62	......	......	......	......	......	......	......
				3	......	39.80	60.20	......	.66	......	......	......	......	......	......	......
Dominguez, 2½ miles northeast of; Wells Gulch, Gunnison Valley; sec. 17, T. 4 S., R. 3 E.; Wells Gulch mine (in main entry, about 200 feet from mouth of mine, 3-foot 11-inch bed, 1-foot 8-inch cut).	165	11106	B	1	3.45	38.81	51.75	5.99	.98	......	......	......	......	.5	7,281	13,107
				2	......	40.20	53.60	6.20	1.01	......	......	......	......	......	7,541	13,574
				3	......	42.86	57.14	......	1.08	......	......	......	......	......	8,039	14,471
EL PASO COUNTY.																
Calhan, 9 miles south of; sec. 18, T. 13 S., R. 62 W.; Mosby mine, Mosby bed (at face of entry, 30 feet from shaft bottom, 4-foot 8-inch bed, 4-foot 4-inch cut).	165	*10732	B	1	33.13	25.95	27.03	13.89	.30	6.48	37.25	.68	41.40	20.8	3,444	6,199
				2	......	38.81	40.42	20.77	.45	4.19	55.70	1.02	17.87	......	5,150	9,270
				3	......	48.98	51.02	......	.57	5.29	70.30	1.29	22.55	......	6,500	11,700
Pikeview, 1 mile north of; sec. 18, T. 13 S., R. 66 W.; Pikeview mine, "A" bed (face of north entry 2, 4,000 feet northwest of shaft, 10-foot 6-inch bed, 7-foot 5-inch cut.)	166	12099	A	1	26.20	29.67	37.67	6.46	.30	6.13	49.36	.66	37.09	7.8	4,640	8,352
				2	......	40.20	51.05	8.75	.41	4.36	66.88	.89	18.71	......	6,287	11,317
				3	......	44.06	55.94	......	.45	4.78	73.29	.98	20.50	......	6,890	12,402
Ramah, 3 miles southwest of; sec. 27, T. 11 S., R. 61 W.; Purdon mine, Purdon bed (face of workings, about 700 feet from entry, 6-foot 9½-inch bed, 6-foot 6-inch cut).	166	*10741	B	1	33.66	23.46	24.67	18.21	.32	6.31	33.21	.54	41.41	25.2	3,059	5,506
				2	......	35.36	37.19	27.45	.48	3.87	50.06	.81	17.33	......	4,611	8,300
				3	......	48.74	51.26	......	.66	5.33	69.00	1.12	23.89	......	6,356	11,441
FREMONT COUNTY.																
Chandler; sec. 22, T. 19 S., R. 70 W.; Chandler mine, Canon bed (face of east entry 9, 4-foot 8-inch bed, 4-foot 2-inch cut).	167	13393	A	1	9.70	38.08	46.19	6.03	.46	......	......	......	......	5.2	......	......
				2	......	42.17	51.15	6.68	.51	......	......	......	......	......	......	......
				3	......	45.19	54.81	......	.55	......	......	......	......	......	......	......

Same (face of main slope, 4-foot 9-inch bed and cut)	167	13394	A	1	10.74	37.92	44.36	6.98	.42	......	......	......	......	6.4	......	......
				2	......	42.48	49.70	7.82	.47	......	......	......	......	......	......	......
				3	......	46.08	53.92	......	.51	......	......	......	......	......	......	......
Same (composite of samples 13393 and 13394).....	167	13395	A	1	10.27	38.25	44.99	6.49	.42	5.38	65.45	1.08	21.18	5.8	6,342	11,416
				2	......	42.63	50.14	7.23	.47	4.74	72.94	1.20	13.42	......	7,068	12,722
				3	......	45.95	54.05	......	.51	5.11	78.62	1.29	14.47	......	7,619	13,714
Rockvale; secs. 25 and 36, T. 19 S., R. 70 W., and secs. 30 and 31, T. 19 S., R. 69 W.; Rockvale mine, Rockvale bed (face of room 39, off third dip, about 6,000 feet south of shaft, 3-foot 9½-inch bed and cut).	167	11938	A	1	8.10	35.22	49.63	7.05	.59	......	......	......	......	2.8	......	......
				2	......	38.32	54.01	7.67	.64	......	......	......	......	......	......	......
				3	......	41.50	58.50	......	.69	......	......	......	......	......	......	......
Same (face of room 31, off fourth dip, 6,200 feet south of shaft, 3-foot 9-inch bed and cut).	167	11939	A	1	8.97	33.78	45.24	12.01	.60	......	......	......	......	3.7	......	......
				2	......	37.11	49.70	13,19	.66	......	......	......	......	......	......	......
				3	......	42.75	57.25	......	.76	......	......	......	......	......	......	......
Same (composite of samples 11938 and 11939).....	167	11941	A	1	8.41	33.70	48.27	9.62	.59	5.28	64.09	1.18	19.24	3.3	6,272	11,290
				2	......	36.79	52.71	10.50	.64	4.75	69.97	1.29	12.85	......	6,848	12,326
				3	......	41.11	58.89	......	.72	5.31	78.18	1.44	14.35	......	7,651	13,772
GARFIELD COUNTY.																
Newcastle, 2 miles east of; sec. 1, T. 6 S., R. 91 W.; Vulcan mine, Allen bed (face of east entry on third level, 1,250 feet southeast of main opening, 10-foot 6-inch bed and cut).	168	12325	A	1	7.13	39.71	48.09	5.07	.41	......	......	......	......	3.6	......	......
				2	......	42.76	51.78	5.46	.44	......	......	......	......	......	......	......
				3	......	45.23	54.77	......	.47	......	......	......	......	......	......	......
Same (face of Allen entry on second level, 1,700 feet from mouth of entry, 10-foot bed and cut).	168	12326	A	1	......	......	......	......	......	......	......	......	......	......	......	......
				2	......	44.39	49.93	5.68	.51	......	......	......	......	......	......	......
				3	......	47.06	52.94	......	.54	......	......	......	......	......	......	......
Same (composite of samples 12325 and 12326).....	168	12327	A	1	7.12	40.75	46.94	5.19	.45	5.65	70.77	1.56	16.38	3.6	7,012	12,622
				2	......	43.88	50.53	5.59	.48	5.23	76.20	1.68	10.82	......	7,550	13,590
				3	......	46.48	53.52	......	.51	5.54	80.71	1.78	11.46	......	7,997	14,395
Same (face of room 15, 250 feet up from entry and 1,000 feet southeast of mine mouth, 10-foot bed and cut).	168	12420	A	1	4.45	42.05	49.56	3.94	.44	5.43	72.57	1.72	15.90	1.3	7,294	13,129
				2	......	44.01	51.87	4.12	.46	5.17	75.95	1.80	12.50	......	7,634	13,741
				3	......	45.90	54.10	......	.48	5.39	79.22	1.88	13.03	......	7,962	14,332
South Cañon; South Cañon mine, Wheeler bed (in main entry, 800 feet from portal, 5-foot 9-inch cut).	169	15166	A	1	7.40	38.99	48.12	5.49	.54	......	......	......	......	3.1	6,729	12,112
				2	......	42.11	51.96	5.93	.58	......	......	......	......	......	7,267	13,081
				3	......	44.76	55.24	......	.62	......	......	......	......	......	7,725	13,905
Same (face of main entry, 1,600 feet from portal, 17-foot 8-inch bed, 7-foot 8-inch cut).	169	15167	A	1	8.31	36.29	44.74	10.66	.52	5.19	62.87	1.43	19.33	3.4	6,231	11,216
				2	......	39.58	48.79	11.63	.57	4.66	68.57	1.56	13.01	......	6,796	12,233
				3	......	44.79	55.21	......	.65	5.27	77.59	1.77	14.72	......	7,690	13,842
GUNNISON COUNTY.																
Somerset, near; Somerset mine (face of room 46, off west entry 6, 10,000 feet north of entry mouth, 12-foot bed, 11-foot 9-inch cut).	170	12322	A	1	5.72	37.45	48.11	8.72	.39	......	......	......	......	1.6	......	......
				2	......	39.72	51.03	9.25	.41	......	......	......	......	......	......	......
				3	......	43.77	56.23	......	.45	......	......	......	......	......	......	......
Same (face of west entry 9, 4,500 feet north of entry mouth, 8-foot bed, 7-foot 9-inch cut).	170	12323	A	1	5.40	37.71	47.21	9.68	.48	......	......	......	......	1.7	......	......
				2	......	39.86	49.91	10.23	.51	......	......	......	......	......	......	......
				3	......	44.40	55.60	......	.57	......	......	......	......	......	......	......
Same (composite of samples 12322 and 12323).....	170	12324	A	1	5.61	37.60	47.57	9.22	.43	5.31	69.68	1.40	13.96	1.7	6,908	12,434
				2	......	39.83	50.40	9.77	.46	4.97	73.82	1.48	9.50	......	7,318	13,172
				3	......	44.14	55.86	......	.51	5.51	81.81	1.64	10.53	......	8,111	14,600

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
COLORADO—Continued.																
HUERFANO COUNTY.																
Oakview, 7 miles west of La Veta; sec. 10, T. 29 S., R. 68 W.; Oakdale mine (face of room 11, off second "cross," off main entry, 13-foot 10-inch bed and cut).	170	13526	A	1	6.79	38.59	45.78	8.84	0.56	......	......	......	......	2.6	......	......
				2	......	41.40	49.12	9.48	.60	......	......	......	......	......	......	......
				3	......	45.73	54.27	......	.66	......	......	......	......	......	......	......
Same (face of main entry, 6-foot 6-inch cut).......	170	13527	A	1	8.56	38.67	43.65	9.12	.57	......	......	......	......	4.6	......	......
				2	......	42.29	47.74	9.97	.62	......	......	......	......	......	......	......
				3	......	46.97	53.03	......	.69	......	......	......	......	......	......	......
Same (composite of samples 13526 and 13527).....	170	13529	A	1	7.80	38.50	44.80	8.90	.53	5.17	65.48	1.09	18.83	3.6	6,412	11,542
				2	......	41.76	48.59	9.65	.57	4.66	71.02	1.18	12.92	......	6,954	12,517
				3	......	46.22	53.78	......	.63	5.16	78.60	1.31	14.30	......	7,697	13,855
Same (sample of natural coke, face of north entry 4, 3-foot 6-inch cut).	170	13528	A	1	12.84	9.35	67.30	10.51	.44	......	......	......	......	11.5	6,365	11,457
				2	......	10.73	77.21	12.06	.50	......	......	......	......	......	7,303	13,145
				3	......	12.20	87.80	......	.57	......	......	......	......	......	8,304	14,947
JACKSON COUNTY.																
Coalmont; NW. ¼ SW. ¼ sec. 24, T. 7 N., R. 81 W.; Riach mine, Riach bed (at breast, about 225 feet east of opening, 77-foot bed, 7-foot cut).	171	12601	B	1	22.81	36.21	34.08	6.90	.70	6.30	51.74	1.14	33.22	5.9	5,004	9,007
				2	......	46.91	44.15	8.94	.91	4.88	67.03	1.48	16.76	......	6,483	11,669
				3	......	51.52	48.48	......	1.00	5.36	73.61	1.63	18.40	......	7,120	12,816
Higho, 8 miles northwest of; SW. ¼ SE. ¼ sec. 24, T. 8 N., R. 82 W.; Mitchell mine, Mitchell bed (275 feet northeast of entry mouth, 8-foot cut).	171	* 12539	B	1	20.72	33.65	35.67	9.96	.83	6.32	51.27	1.27	30.35	4.1	5,024	9,043
				2	......	42.45	44.99	12.56	1.05	5.07	64.67	1.60	15.05	......	6,337	11,407
				3	......	48.55	51.45	......	1.20	5.80	73.96	1.83	17.21	......	7,247	13,045
4 miles northwest of, 18 miles northwest of Walden; SE. ¼ SE. ¼ sec. 31, T. 10 N., R. 81 W.; Monahan mine, Monahan bed (face of slope, 125 feet east of mine mouth, 4-foot 6-inch bed and cut.)	172	*12540	B	1	19.70	32.77	44.06	3.47	.68	6.39	57.70	1.49	30.27	4.8	5,716	10,289
				2	......	40.81	54.87	4.32	.85	5.23	71.85	1.86	15.89	......	7,118	12,812
				3	......	42.65	57.35	......	.89	5.47	75.09	1.94	16.61	......	7,439	13,390
Walden, 5 miles northeast of; NE. ¼ NE. ¼ sec. 18, T. 9 N., R. 78 W.; McCallum mine, Sudduth bed (face of entry about 50 feet from mouth of entry, 35-foot bed, 7-foot cut).	172	* 12774	B	1	19.18	33.48	41.05	6.29	.27	5.75	56.34	.82	30.53	5.2	5,353	9,635
				2	......	41.42	50.80	7.78	.33	4.48	69.71	1.01	16.69	......	6,623	11,921
				3	......	44.92	55.08	......	.36	4.86	75.59	1.10	18.09	......	7,182	12,928

8½ miles from; NW. ¼ NE. ¼ sec. 35, T. 9 N., R. 78 W.; Marr mine, Sudduth bed (inside mouth of entry, water beyond, 53-foot bed, 6-foot cut).	172	*12415	B	1	16.72	33.02	46.67	3.59	.16	5.63	60.20	.70	29.72	7.4	5,755	10,359
				2	....	39.65	56.04	4.31	.19	4.53	72.29	.84	17.84	....	6,911	12,440
				3	....	41.43	58.57	....	.20	4.73	75.54	.88	18.65	....	7,222	13,000
7½ miles from; NW. ¼ SW. ¼ sec. 15, T. 9 N., R. 78 W.; Sudduth mine, Sudduth bed (face of main entry about 70 feet in, 50-foot bed, 20-foot cut).	172	*12414	B	1	19.97	32.54	42.49	5.00	.59	5.82	57.05	.78	30.76	8.2	5,419	9,754
				2	....	40.66	53.09	6.25	.74	4.50	71.28	.97	16.26	....	6,741	12,188
				3	....	43.37	56.63	....	.79	4.80	76.03	1.03	17.35	....	7,223	13,001
10½ miles southeast of; SW. ¼ NE. ¼ sec. 14, T. 8 N., R. 78 W.; Winscom mine, Winscom bed (in entry, about 125 feet northeast of mine mouth, 4-foot 5-inch bed, 2-foot 7-inch cut).	173	*12775	B	1	18.06	34.49	35.32	12.13	.80	5.82	52.44	1.11	27.70	5.2	5,153	9,275
				2	....	42.09	43.11	14.80	.98	4.65	64.00	1.35	14.22	....	6,289	11,320
				3	....	49.40	50.60	....	1.15	5.46	75.12	1.58	16.69	....	7,381	13,286
JEFFERSON COUNTY.																
Morrison, 2½ miles from, 6 miles from Golden; secs. 23, 24, 25, 26, T. 4 S., R. 70 W.; White Ash mine, Jumbo bed (30 feet up from second level, 75 feet from shaft, 16-foot bed, 10-foot 6-inch cut).	173	*16615	A	1	28.67	30.69	34.85	5.79	.75	6.35	47.94	.69	38.48	15.8	4,533	8,159
				2	....	43.02	48.86	8.12	1.05	4.43	67.21	.97	18.22	....	6,355	11,439
				3	....	46.82	53.18	....	1.14	4.82	73.15	1.06	19.83	....	6,917	12,451
LA PLATA COUNTY.																
Durango, 1¼ miles southwest of; T. 35 N., R. 10 W.; San Juan mine, Mesaverde formation (face of main entry, 1,200 feet west of mine mouth, 3-foot 1-inch bed, 3-foot cut).	174	14770	A	1	3.83	34.42	55.29	6.46	.68	....	....	....	....	2.7	....	....
				2	....	35.79	57.49	6.72	.71	....	....	....	....	....	....	....
				3	....	38.37	61.63	....	.76	....	....	....	....	....	....	....
Same (face of room 6, off first dip entry south, 300 feet from mine mouth, 5-foot 2-inch bed, 5-foot cut).	174	14771	A	1	2.24	34.06	56.49	7.21	.74	....	....	....	....	1.2	....	....
				2	....	34.84	57.78	7.38	.76	....	....	....	....	....	....	....
				3	....	37.62	62.38	....	.82	....	....	....	....	....	....	....
Same (composite of samples 14770 and 14771).....	174	14772	A	1	3.01	34.77	55.31	6.91	.74	5.50	76.36	1.50	8.99	2.0	7,619	13,714
				2	....	35.85	57.03	7.12	.76	5.33	78.73	1.55	6.51	....	7,855	14,139
				3	....	38.60	61.40	....	.82	5.74	84.77	1.67	7.00	....	8,457	15,223
Hesperus, 16 miles west of Durango; sec. 14, T. 35 N., R. 11 W.; Hesperus mine, Mesaverde formation (face of room 3, off right entry 4; 4,000 feet from mine mouth, 5-foot 2½-inch bed, 5-foot 2-inch cut).	175	14773	A	1	7.57	38.01	47.75	6.67	.70	....	....	....	....	4.2	....	....
				2	....	41.12	51.66	7.22	.76	....	....	....	....	....	....	....
				3	....	44.32	55.68	....	.82	....	....	....	....	....	....	....
Same (room 5, off left entry 5; 4,000 feet west of mine mouth, 4-foot 7-inch bed, 4-foot 6-inch cut).	175	14774	A	1	6.59	38.94	49.31	5.16	.62	....	....	....	....	3.4	....	....
				2	....	41.69	52.79	5.52	.66	....	....	....	....	....	....	....
				3	....	44.12	55.88	....	.70	....	....	....	....	....	....	....
Same (composite of samples 14773 and 14774).....	175	14775	A	1	7.08	38.10	48.97	5.85	.60	5.68	70.85	1.47	15.55	3.8	7,040	12,672
				2	....	41.00	52.70	6.30	.65	5.26	76.25	1.58	9.96	....	7,576	13,637
				3	....	43.76	56.24	....	.69	5.61	81.37	1.69	10.64	....	8,085	14,553
Perins, 5 miles southeast of Durango; secs. 11 and 14, T. 35 N., R. 10 W.; Perins Peak mine, Mesaverde formation (room 3, off main entry, 3,200 feet from mine mouth, 5-foot 1-inch bed and cut).	175	14776	A	1	6.43	39.00	50.88	3.69	.80	....	....	....	....	4.4	....	....
				2	....	41.68	54.38	3.94	.85	....	....	....	....	....	....	....
				3	....	43.39	56.61	....	.88	....	....	....	....	....	....	....
Same (face of room 13, off main back entry, 5-foot 5-inch bed and cut).	175	14777	A	1	4.05	39.52	49.04	7.39	4.02	....	....	....	....	2.4	....	....
				2	....	41.19	51.11	7.70	4.19	....	....	....	....	....	....	....
				3	....	44.63	55.37	....	4.54	....	....	....	....	....	....	....
Same (composite of samples 14776 and 14777).....	175	14778	A	1	5.31	38.98	50.03	5.68	2.11	5.66	72.83	1.58	12.14	3.4	7,342	13,216
				2	....	41.17	52.83	6.00	2.23	5.35	76.91	1.67	7.84	....	7,754	13,957
				3	....	43.80	56.20	....	2.37	5.69	81.82	1.78	8.34	....	8,249	14,848

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
COLORADO—Continued.																
LAS ANIMAS COUNTY.																
Cokedale; sec. 25, T. 33 S., R. 65 W.; Cokedale mine, Cokedale bed (face of room 8, off west entry 4, 6-foot 1-inch bed, 5-foot 4-inch cut).	176	11768	A	1	2.39	25.07	54.80	17.74	0.52	......	......	......	......	1.6	......	......
				2	......	25.68	56.15	18.17	.53	......	......	......	......	......	......	......
				3	......	31.38	68.62	......	.65	......	......	......	......	......	......	......
Same (face of room 21, off west entry 1, 6-foot 10½-inch bed, 4 foot 9½-inch cut).	176	11769	A	1	2.74	26.77	56.22	14.27	.56	......	......	......	......	2.0	......	......
				2	......	27.52	57.81	14.67	.58	......	......	......	......	......	......	......
				3	......	32.25	67.75	......	.68	......	......	......	......	......	......	......
Same (face of room 10, off west entry 6, 6-foot 1-inch bed, 5-foot 3-inch cut).	176	11770	A	1	2.12	24.85	53.39	19.64	.47	......	......	......	......	1.6	......	......
				3	......	25.39	54.54	20.07	.48	......	......	......	......	......	......	......
				3	......	31.76	68.24	......	.60	......	......	......	......	......	......	......
Same (composite of samples 11768, 11769, and 11770).	176	11771	A	1	2.33	25.82	54.58	17.27	.52	4.62	69.14	1.07	7.38	1.7	6,854	12,337
				2	......	26.44	55.88	17.68	.53	4.46	70.79	1.10	5.44	......	7,018	12,632
				3	......	32.12	67.88	......	.64	5.42	86.00	1.34	6.60	......	8,525	15,345
Delagua, 20 miles north of Trinidad; sec. 15, T. 31 S., R. 65 W.; Delagua mine, Delagua bed (face of room 1, off east entry 24, off north entry 3, 5-foot 8-inch bed and cut).	177	11435	A	1	3.19	35.00	53.22	8.59	.57	......	......	......	......	1.9	......	......
				2	......	36.16	54.97	8.87	.59	......	......	......	......	......	......	......
				3	......	39.68	60.32	......	.65	......	......	......	......	......	......	......
Same (face of east entry 18, off north entry 4, 6-foot 6-inch bed and cut).	177	11436	A	1	3.53	34.23	52.05	10.19	.47	......	......	......	......	2.3	......	......
				2	......	35.48	53.96	10.56	.49	......	......	......	......	......	......	......
				3	......	39.67	60.33	......	.55	......	......	......	......	......	......	......
Same (face of room 5, west entry 3, off north entry 4, 5-foot 8-inch bed, 5-foot 4-inch cut).	177	11437	A	1	3.14	33.37	50.96	12.53	.50	......	......	......	......	2.1	......	......
				2	......	34.45	52.61	12.94	.52	......	......	......	......	......	......	......
				3	......	39.57	60.43	......	.60	......	......	......	......	......	......	......
Same (composite of samples 11435, 11436, and 11437).	177	11443	A	1	3.31	34.34	52.03	10.32	.55	5.09	71.57	1.38	11.09	2.1	7,063	12,713
				2	......	35.51	53.82	10.67	.57	4.88	74.02	1.43	8.43	......	7,305	13,149
				3	......	39.75	60.25	......	.64	5.46	82.86	1.60	9.44	......	8,177	14,719
Forbes; secs. 15 and 16, T. 32 S., R. 64 W.; Forbes No. 9 (or Cox) mine, Walsen bed (face of first crosscut off west entry 1, 2,800 feet southwest of slope opening, 4-foot 4-inch bed and cut).	177	11926	A	1	2.14	30.50	56.99	10.37	.65	......	......	......	......	1.2	......	......
				2	......	31.17	58.23	10.60	.66	......	......	......	......	......	......	......
				3	......	34.87	65.13	......	.74	......	......	......	......	......	......	......

Same (face of west entry 6, 3,800 feet southwest of slope opening, 3-foot 9-inch bed and cut).	177	11927	A	1	2.29	30.53	56.30	10.88	.60					1.5		
				2		31.24	57.63	11.13	.61							
				3		35.15	64.85		.69							
Same (room 6, off west entry 4, 3,200 feet southwest of slope opening, 3-foot 11-inch bed and cut).	178	11929	A	1	1.96	30.22	57.54	10.28	.59					1.1		
				2		30.82	58.69	10.49	.60							
				3		34.43	65.57		.67							
Same (composite of samples 11926, 11927, and 11929).	178	11930	A	1	2.15	30.67	56.64	10.54	.61	5.01	75.31	1.31	7.22	1.3	7,512	13,522
				2		31.34	57.89	10.77	.62	4.87	76.97	1.34	5.43		7,677	13,819
				3		35.12	64.88		.69	5.46	86.26	1.50	6.09		8,604	15,487
Hastings; sec. 25, T. 32 S., R. 64 W.; Hastings mine, Hastings bed (pillar between south entries 7 and 8, 8,300 feet from mouth of slope, 10-foot 5-inch bed, 9-foot 5-inch cut).	178	12028	A	1	2.85	32.65	55.26	9.24	.62	5.16	74.39	1.35	9.24	1.6	7,368	13,262
				2		33.61	56.88	9.51	.64	4.99	76.57	1.39	6.90		7,584	13,651
				3		37.14	62.86		.71	5.51	84.62	1.54	7.62		8,381	15,086
Same (in south entry 7, at fifth crosscut, 8,200 feet from mouth of slope).	178	12031	A	1	10.12	26.06	41.99	21.83	.51					8.9		
				2		28.99	46.72	24.29	.57							
				3		38.29	61.71		.75							
Berwind (?) bed (face of slope, 5-foot 1-inch bed and cut).	178	12029	A	1	2.52	32.21	48.25	17.02	.92	4.92	66.47	1.20	9.47	1.7	6,661	11,990
				2		33.04	49.50	17.46	.94	4.76	68.19	1.23	7.42		6,834	12.301
				3		40.03	59.97		1.14	5.77	82.61	1.49	8.99		8,279	14,902
Morley; Morley mine, Engle-Starkville bed (face of room 2, third plane, off right entry 4, 5-foot 3-inch bed and cut).	179	13361	A	1	2.13	32.68	53.57	11.62	.69					1.6		
				2		33.39	54.74	11.87	.71							
				3		37.89	62.11		.81							
Same (face of left entry 5, 6-foot 1-inch bed and cut).	179	13362	A	1	3.60	31.71	45.67	19.02	1.12					3.1		
				2		32.89	47.38	19.73	1.16							
				3		40.97	59.03		1.45							
Same (face of right entry 4, 3,000 feet from mine mouth, 5-foot 1-inch bed and cut).	179	13363	A	1	4.25	31.91	47.31	16.53	.56					3.7		
				2		33.33	49.41	17.26	.58							
				3		40.28	59.72		.70							
Same (composite of samples 13361, 13362, and 13363).	179	13364	A	1	3.32	31.98	49.09	15.61	.82	4.93	67.66	1.23	9.75	2.8	6,865	12,357
				2		33.08	50.77	16.15	.85	4.72	69.98	1.27	7.03		7,100	12,780
				3		39.45	60.55		1.01	5.63	83.46	1.51	8.39		8,467	15,241
Primero; secs. 23, 24, 25, and 26, T. 33 S., R. 66 W.; First East Primero mine, Primero bed (pillar of right entry 6, between rooms 1 and 2, off entry B-8, off blind entry 3, 6-foot 1-inch bed and cut).	180	W31143	A	1	1.9	30.8	51.5	15.8	.80						7,011	12,620
				2		31.4	52.5	16.1	.80						7,144	12,860
				3		37.4	62.6		.95						8,517	15,330
Same (pillar of room 5, off west entry B-9, off blind entry 1, 5-foot 1-inch bed and cut).	180	W31144	A	1	1.4	33.0	53.9	11.7	.50						7,411	13,340
				2		33.5	54.6	11.9	.50						7,517	13,530
				3		38.0	62.0		.57						8,533	15,360
Same (chain pillar of east entry B-9, 6-foot 5-inch bed and cut).	180	W31145	A	1	1.6	29.6	55.4	13.4	.50						7,233	13,020
				2		30.1	56.3	13.6	.50						7,356	13,240
				3		34.8	65.2		.58						8,511	15,320
Same (face of room 4, off east entry B-10, 5-foot 11-inch bed and cut).	180	W31146	A	1	1.4	31.7	55.0	11.9	.45						7,428	13,370
				2		32.2	55.7	12.1	.45						7,539	13,570
				3		36.6	63.4		.51						8,578	15,440
Same (face of room 3, off east entry 11, 7-foot 4-inch bed and cut).	181	W31147	A	1	2.0	29.0	56.1	12.9	.60						7,256	13,060
				2		29.6	57.2	13.2	.60						7,406	13,330
				3		34.1	65.9		.69						8,533	15,360
Same (chain pillar of east entry B-10, off blind entry 3, 7-foot bed and cut).	181	W31149	A	1	1.0	28.3	56.5	14.2	.55						7,233	13,020
				2		28.6	57.1	14.3	.55						7,306	13,150
				3		33.4	66.6		.64						8,528	15,350

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
COLORADO—Continued.																
LAS ANIMAS COUNTY—continued.																
Primero; secs. 23, 24, 25, and 26, T. 33 S., R. 66 W.; First East Primero mine, Primero bed (composite of samples 31143–31149).	181	14060	A	1	1.53	30.78	54.37	13.32	0.53	4.98	73.10	1.71	6.36	0.6	7,221	12,998
				2	......	31.26	55.21	13.53	.54	4.88	74.23	1.74	5.08	......	7,333	13,199
				3	......	36.15	63.85	......	.62	5.64	85.85	2.01	5.88	......	8,481	15,266
Same (taken from cars while being loaded at the mine).	182	W31131	C	1	1.2	30.5	55.7	12.6	.60	......	......	......	......	......	7,311	13,160
				2	......	30.9	56.3	12.8	.60	......	......	......	......	......	7,400	13,320
				3	......	35.4	64.6	......	.69	......	......	......	......	......	8,483	15,270
Same (taken from same cars as sample 31131).....	182	W31132	C	1	1.2	30.5	55.7	12.6	.50	......	......	......	......	......	7,328	1,3190
				2	......	30.9	56.3	12.8	.50	......	......	......	......	......	7,417	1,3350
				3	......	35.4	64.6	......	.57	......	......	......	......	......	8,506	1,5310
Same (taken from four cars while being loaded at the mine).	182	W31133	C	1	1.0	30.1	55.1	13.8	.50	......	......	......	......	......	7,228	1,3010
				2	......	30.4	55.7	13.9	.50	......	......	......	......	......	7,300	1,3140
				3	......	35.3	64.7	......	.58	......	......	......	......	......	8,478	1,5260
Same (taken from same cars as sample 31133).....	182	W31134	C	1	1.0	30.7	54.8	13.5	.50	......	......	......	......	......	7,233	1,3020
				2	......	31.0	55.4	13.6	.50	......	......	......	......	......	7,311	1,3160
				3	......	35.9	64.1	......	.58	......	......	......	......	......	8,567	1,5240
Same (taken from four cars while being loaded at the mine).	182	W31135	C	1	1.0	30.3	58.0	10.7	.50	......	......	......	......	......	7,367	1,3260
				2	......	30.6	58.6	10.8	.50	......	......	......	......	......	7,444	1,3400
				3	......	34.3	65.7	......	.56	......	......	......	......	......	8,344	1,5020
Same (taken from same cars as sample 31135).....	182	W31136	C	1	1.0	30.4	56.1	12.5	.50	......	......	......	......	......	7,356	1,3240
				2	......	30.7	56.7	12.6	.50	......	......	......	......	......	7,428	1,3370
				3	......	35.1	64.9	......	.57	......	......	......	......	......	8,500	1,5300
Same (taken from four cars while being loaded at the mine).	182	W31137	C	1	1.1	29.9	56.0	13.0	.55	......	......	......	......	......	7,317	13,170
				2	......	30.2	56.7	13.1	.55	......	......	......	......	......	7,394	13,310
				3	......	34.8	65.2	......	.63	......	......	......	......	......	8,511	15,320
Same (taken from same cars as sample 31137).....	182	W31138	C	1	1.1	30.3	55.2	13.4	.50	......	......	......	......	......	7,283	13,110
				2	......	30.6	55.8	13.6	.50	......	......	......	......	......	7,367	13,260
				3	......	35.4	64.6	......	.58	......	......	......	......	......	8,522	15,340
First North Primero mine, Primero bed (room 5, off back entry 3, off entry A-12, 7-foot 11-inch bed and cut).	181	W31148	A	1	1.6	27.1	59.1	12.2	.50	......	......	......	......	......	7,367	13,260
				2	......	27.5	60.1	12.4	.50	......	......	......	......	......	7,489	13,480
				3	......	31.4	68.6	......	.57	......	......	......	......	......	8,557	15,390
Same (pillar of room 7, off entry A-12, 7-foot bed, 6-foot 11-inch cut).	181	W31150	A	1	1.5	31.8	53.3	13.4	.55	......	......	......	......	......	7,217	12,990
				2	......	32.3	54.1	13.6	.55	......	......	......	......	......	7,328	13,190
				3	......	37.4	62.6	......	.64	......	......	......	......	......	8,483	15,270

Same (face of entry B-9, 7-foot 2-inch bed, 7-foot ½-inch cut).	181	W31151	A	1	1.9	30.6	54.7	12.8	.55						7,317	13,170
				2		31.2	55.8	13.0	.55						7,456	13,420
				3		35.9	64.1		.63						8,572	15,430
Same (composite of samples W31148, W31150, and W31151).	181	14059	A	1	1.42	32.31	53.33	12.94	.50	5.04	73.46	1.71	6.35	.5	7,267	13,081
				2		32.78	54.09	13.13	.51	4.95	74.52	1.73	5.16		7,372	13,270
				3		37.73	62.27		.59	5.70	85.78	1.99	5.94		8,486	15,275
Same (taken from four cars while being loaded at the mine).	182	W31033	C	1	2.1	29.5	54.7	13.7	.60						7,150	12,870
				2		30.1	55.9	14.0	.60						7,306	13,150
				3		35.0	65.0		.70						8,494	15,290
Same (taken from same cars as sample 31033).....	182	W31034	C	1	1.1	30.8	54.0	14.1	.50						7,189	12,940
				2		31.1	54.6	14.3	.50						7,272	13,090
				3		36.3	63.7		.58						8,483	15,270
Same (taken from four cars while being loaded at the mine).	182	W31035	C	1	1.2	31.4	55.3	12.1	.59						7,389	13,300
				2		31.8	56.0	12.2	.50						7,478	13,460
				3		36.2	63.8		.57						8,517	15,330
Same (taken from same cars as sample 31035).....	182	W31036	C	1	1.1	31.2	55.4	12.3	.50						7,344	13,220
				2		31.6	56.0	12.4	.50						7,428	13,370
				3		36.1	63.9		.57						8,478	15,260
First West Primero mine, Primero bed (face of north entry 2, 4-foot 9-inch bed, 4-foot 5½-inch cut).	181	W31039	A	1	2.2	30.7	51.8	15.3	.65						7,011	12,620
				2		31.4	53.0	15.6	.65						7,167	12,900
				3		37.2	62.8		.77						8,489	15,280
Same (face of room 10, off north entry 1, 5-foot 4-inch bed and cut).	181	W31040	A	1	1.9	31.0	50.7	16.4	.60						6,933	12,480
				2		31.6	51.7	16.7	.60						7,072	12,730
				3		37.9	62.1		.72						8,489	15,280
Same (face of room 9, off south entry 2, 4-foot 9-inch bed, 4-foot 7-inch cut).	181	W31041	A	1	2.0	31.1	52.3	14.6	.55						7,072	12,730
				2		31.7	53.4	14.9	.55						7,217	12,990
				3		37.3	62.7		.65						8,483	15,270
Same (face of room 5, off right entry 1, off first west air course, 5-foot bed, 4-foot 7½-inch cut).	181	W31042	A	1	2.1	31.1	54.0	12.8	.60						7,283	13,110
				2		31.8	55.1	13.1	.60						7,439	13,390
				3		36.6	63.4		.69						8,561	15,410
Same (face of room 17, off right entry 2, off first west air course, 5-foot bed and cut).	181	W31043	A	1	2.8	30.4	51.2	15.6	.55						6,922	12,460
				2		31.3	52.7	16.0	.55						7,117	12,810
				3		37.3	62.7		.65						8,472	15,250
Same (composite of samples W31039, W31040, W31041, W31042, and W31043).	181	14058	A	1	2.02	30.38	52.80	14.80	.60	4.94	71.36	1.66	6.64	1.0	7,052	12,694
				2		31:01	53.89	15.10	.61	4.82	72.83	1.69	4.95		7,197	12,955
				3		36.53	63.47		.72	5.68	85.79	1.99	5.82		8,477	15,259
Same (taken from 4 cars while being loaded at the mine.	182	W31037	C	1	1.3	29.6	51.9	17.2	.50						6,900	12,420
				2		30.0	52.6	17.4	.50						6,994	12,590
				3		36.3	63.7		.61						8,467	15,240
Same (taken from same cars as sample 31037)....	182	W31038	C	1	1.2	30.1	51.5	17.2	.60						6,900	12,420
				2		30.5	52.1	17.4	.60						6,989	12,580
				3		36.9	63.1		.73						8,461	15,230
Same (taken from car while being loaded at the mine).	182	W31139	C	1	1.2	29.8	52.0	17.0	.65						6,944	12,500
				2		30.2	52.6	17.2	.65						7,028	12,650
				3		36.5	63.5		.79						8,483	15,270
Same (taken from same car as sample 31139)......	182	W31140	C	1	1.1	29.2	52.7	17.0	.60						6,928	12,470
				2		29.5	53.3	17.2	.60						7,006	12,610
				3		35.6	64.4		.72						8,461	15,230
Same (taken from 4 cars while being loaded at the mine).	182	W31141	C	1	1.4	28.9	53.0	16.7	.60						6,933	12,480
				2		29.3	53.8	16.9	.60						7,033	12,660
				8		35.3	64.7		.72						8,461	15,230

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
COLORADO—Continued.																
LAS ANIMAS COUNTY—continued.																
Primero; secs. 23, 24, 25, and 26, T. 33 S., R. 66 W.; First West Primero mine, Primero bed (taken from same cars as sample 31141).	182	W31142	C	1	1.3	28.6	52.3	17.8	0.60	......	......	......	......	......	6,828	12,290
				2	......	29.0	53.0	18.0	.60	......	......	......	......	......	6,922	12,460
				3	......	35.4	64.6	......	.73	......	......	......	......	......	8,439	15,190
Primero mine, Primero bed (face of room 1 off second blind back entry, 5-foot 10-inch bed and cut).	180	12025	A	1	2.36	31.07	56.65	9.92	.59	5.06	74.54	1.65	8.24	1.6	7,503	13,505
				2	......	31.82	58.02	10.16	.60	4.92	76.34	1.69	6.29	......	7,685	13,833
				3	......	35.42	64.58	......	.67	5.48	84.97	1.88	7.00	......	8,554	15,397
Same (face of first west slope, 1,500 feet from mouth).	180	12027	A	1	3.98	27.96	50.50	17.56	.51	......	......	......	......	3.0	......	......
				2	......	29.12	52.59	18.29	.53	......	......	......	......	......	......	......
				3	......	35.64	64.36	......	.65	......	......	......	......	......	......	......
Starkville; Starkville mine, Engle-Starkville bed (rib of west entry 8, 30 feet outby slant from new entry, 7-foot 2¾-inch bed, 6-foot 9¾-inch cut).	182	11134	A	1	2.07	29.15	55.56	13.22	.57	4.64	71.77	1.15	8.65	.8	7,139	12,850
				2	......	29.77	56.73	13.50	.58	4.50	73.28	1.17	6.97	......	7,290	13,122
				3	......	34.42	65.58	......	.67	5.20	84.72	1.36	8.06	......	8,428	15,170
Same (south entry 3, near second crosscut off new entry, 2-foot 11½-inch cut).	182	11135	A	1	1.79	28.67	55.33	14.21	.62	4.69	71.76	1.15	7.57	.8	7,074	12,733
				2	......	29.19	56.34	14.47	.63	4.57	73.07	1.17	6.09	......	7,203	12,965
				3	......	34.13	65.87	......	.74	5.34	85.43	1.37	7.12	......	8,422	15,160
Same (entry I-5 between rooms 26 and 27, on pillar, 15,000 feet southwest of mine mouth, 5-foot 9-inch bed and cut).	182	12196	A	1	1.81	31.16	55.49	11.54	.60	......	......	......	......	.7	......	......
				2	......	31.73	56.52	11.75	.61	......	......	......	......	......	......	......
				3	......	35.95	64.05	......	.69	......	......	......	......	......	......	......
Same (face of south entry 1, 1,200 feet southeast of mine mouth, 4-foot 2-inch cut).	182	12197	A	1	2.97	25.89	49.80	21.34	.54	......	......	......	......	1.8	......	......
				2	......	26.68	51.33	21.99	.56	......	......	......	......	......	......	......
				3	......	34.20	65.80	......	.72	......	......	......	......	......	......	......
Same (composite of samples 12196 and 12197).....	183	12198	A	1	2.50	28.85	52.09	16.56	.55	4.79	69.12	1.10	7.88	1.3	6,881	12,386
				2	......	29.59	53.43	16.98	.56	4.63	70.89	1.13	5.81	......	7,057	12,703
				3	......	35.64	64.36	......	.67	5.58	85.39	1.36	7.00	......	8,500	15,300
Tollerburg; Toller mine, Berwind bed; (face of slope, 2,500 feet from shaft bottom, 7-foot bed and cut).	183	13253	A	1	6.31	30.15	49.45	14.09	.65	5.10	67.46	1.31	11.39	5.5	6,747	12,145
				2	......	32.18	52.78	15.04	.69	4.70	72.00	1.40	6.17	......	7,201	12,962
				3	......	37.88	62.12	......	.81	5.53	84.74	1.65	7.27	......	8,476	15,257
Same (face of north entry 5, 3,000 feet from shaft bottom, 7-foot bed and cut).	183	13254	A	1	5.43	33.01	52.93	8.63	.63	5.46	72.98	1.35	10.95	4.6	7,354	13,237
				2	......	34.90	55.97	9.13	.67	5.14	77.17	1.43	6.46	......	7,776	13,997
				3	......	38.41	61.59	......	.74	5.66	84.93	1.57	7.10	......	8,557	15,403

MESA COUNTY.																
Grand Junction, 1 mile south of; sec. 26, T. 1 S., R. 1 W.; prospect (in entry, about 125 feet from opening, 3-foot 11-inch bed, 1-foot 11-inch cut).	184	11108	B	1	5.13	27.94	38.74	28.19	1.14					1.9	5,147	9,265
				2		29.45	40.83	29.72	1.20						5,425	9,765
				3		41.90	58.10		1.72						7,719	13,894
Same (in entry, about 125 feet from opening, 2-foot 10-inch bed, 10-inch cut).	184	11109	B	1	5.69	26.34	34.21	33.76	.80					2.1	4,648	8,366
				2		27.93	36.27	35.80	.85						4,928	8,870
				3		43.50	56.50		1.32						7,676	13,817
5 miles southeast of; sec. 5, T. 2 S., R. 1 E.; prospect (in entry, 100 feet from opening, 2-foot 6-inch bed, cut taken from upper 15 inches).	184	11104	B	1	3.51	39.19	51.33	5.97	1.67					.7	7,251	13,052
				2		40.62	53.19	6.19	1.73						7,515	13,527
				3		43.30	56.70		1.84						8,011	14,420
Same (position and bed same as sample 11104, cut taken from lower 12 inches).	184	11105	B	1	3.18	29.11	45.29	22.42	1.19					.7	5,840	10,512
				2		30.06	46.78	23.16	1.23						6,032	10,858
				3		39.12	60.88		1.60						7,850	14,130
MOFFAT COUNTY.																
Axial, 6 miles west of; NW. ¼ sec. 14, T. 4 N., R. 94 W.; Battle Era mine (in main entry, 130 feet northeast of mine mouth; 11-foot 6-inch bed, 11-foot cut).	185	*14528	B	1	14.67	36.65	42.56	6.12	.89	5.54	59.06	1.33	27.06	1.3	5,634	10,141
				2		42.95	49.88	7.17	1.04	4.58	69.21	1.56	16.44		6,602	11,884
				3		46.27	53.73		1.12	4.93	74.55	1.68	17.72		7,112	12,802
5½ miles northwest of; sec. 13, T. 4 N., R. 94 W.; Ed. Collom mine (75 feet northwest of opening, 13-foot 6-inch bed and cut).	185	*14529	B	1	14.84	38.68	42.66	3.82	.66	5.87	61.49	1.17	26.99	2.0	5,989	10,780
				2		45.42	50.09	4.49	.78	4.96	72.21	1.37	16.19		7,033	12,659
				3		47.55	52.45		.82	5.19	75.60	1.43	16.96		7,364	13,255
Sec. 14, T. 3 N., R. 93 W.; James mine (in main entry, 100 feet north of opening, 6-foot 4-inch bed and cut).	185	12704	B	1	11.42	40.24	44.47	3.87	.54	5.57	65.27	1.32	23.43	.8	6,310	11,358
				2		45.43	50.20	4.37	.61	4.85	73.68	1.49	15.00		7,123	12,821
				3		47.51	52.49		.64	5.07	77.05	1.56	15.68		7,449	13,408
1½ miles south of; sec. 2, T. 3 N., R. 93 W.; Joe Collom mine, Collom bed (in mine, 400 feet northwest of mine mouth; 20-foot 1-inch bed, 8-foot 11-inch cut).	186	*14543	B	1	11.91	40.64	45.24	2.21	.32					2.1	6,451	11,612
				2		46.13	51.36	2.51	.36						7,323	13,181
				3		47.32	52.68		.37						7,511	13,520
2 miles east of; sec. 31, T. 4 N., R. 92 W.; Shafer mine (189 feet northeast of the mine mouth, 14-foot bed, 13-foot 9-inch cut).	186	14909	B	1	13.51	38.50	44.10	3.89	.59	5.80	63.11	1.23	25.38	4.6	6,124	11,023
				2		44.51	50.99	4.50	.68	4.97	72.97	1.42	15.46		7,081	12,746
				3		46.61	53.39		.71	5.20	76.41	1.49	16.19		7,415	13,347
Craig, 3 miles southeast of; Walker mine (face of main entry, 300 feet west of mine mouth, 8-foot bed).	186	12400	A	1	15.54	37.42	39.56	7.48	.97					2.9	5,751	10,352
				2		44.31	46.83	8.86	1.15						6,809	12,256
				3		48.62	51.38		1.26						7,471	13.448
MONTEZUMA COUNTY.																
Cortez, one-half mile west of, 12 miles southwest of Dolores; sec. 23, T. 36 N., R. 16 W.; Cortez mine, lowest bed in Dakota formation (in tunnel, 50 feet from mouth, 4-foot 8½-inch bed, 1-foot 7-inch cut).	187	12785	B	1	8.05	32.27	45.50	14.18	.57	4.72	60.29	1.01	19.23	4.5	5,800	10,439
				2		35.09	49.49	15.42	.62	4.17	65.57	1.10	13.12		6,308	11,354
				3		41.49	58.51		.73	4.93	77.52	1.30	15.52		7,458	13,424
16 miles southwest of; sec. 3, T. 35 N., R. 18 W.; Hamilton prospect, Dakota formation (near surface in open cut, 2-foot 8-inch bed, 1-foot 7-inch cut).	187	12686	B	1	7.74	21.00	58.68	12.58	.46					3.2	6,033	10,859
				2		22.76	63.60	13.64	.50						6,539	11,770
				3		26.35	73.65		.58						7,572	13,630

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
COLORADO—Continued.																
MONTEZUMA COUNTY—continued.																
Cortez, 10 miles southeast of; SW. ¼ NE. ¼ sec. 33, T. 35 N., R. 16 W.; Jackson mine, lower bed of Mesaverde formation, probably Spencer (face of room 4, off north main entry, 200 feet from opening, 2-foot 10-inch bed and cut).	188	16472	A	1	12.20	41.33	40.38	6.09	0.44					4.1	6,309	11,356
				2		47.07	45.99	6.94	.50						7,186	12,935
				3		50.58	49.42		.54						7,722	13,900
Same (face of main entry, 170 feet north from opening, 2-foot 7-inch bed and cut).	188	16473	A	1	12.31	42.23	40.51	4.95	.48					3.8	6,399	11,518
				2		48.16	46.20	5.64	.55						7,297	13,135
				3		51.04	48.96		.58						7,733	13,919
Same (face of south entry, 95 feet from opening, 5-foot 3-inch bed, 2-foot 7-inch cut).	188	16474	A	1	13.79	40.67	39.93	5.61	.49					4.9	6,176	11,117
				2		47.18	46.31	6.51	.57						7,164	12,895
				3		50.46	49.54		.61						7,663	13,793
Same (composite of samples 16472, 16473, and 16474).	189	16475	A	1	12.77	41.34	40.24	5.65	.50	6.10	63.47	1.34	22.94	4.3	6,310	11,358
				2		47.39	46.13	6.48	.57	5.37	72.76	1.54	13.28		7,234	13,021
				3		50.67	49.33		.61	5.74	77.80	1.65	14.20		7,735	13,923
1½ miles southeast of; sec. 35, T. 36 N., R. 16 W.; Mowry mine, Dakota formation (near face, 75 feet from mine mouth, 2-foot 8-inch bed, 2-foot 2-inch cut).	189	12586	B	1	4.84	34.56	42.30	18.30	7.56	4.85	59.90	1.11	8.28	3.1	6,147	11,065
				2		36.32	44.45	19.23	7.94	4.53	62.95	1.17	4.18		6,460	11,628
				3		44.97	55.03		9.83	5.61	77.94	1.45	5.17		7,998	14,396
Same (in main entry, 100 feet from mine mouth, 2-foot 2-inch bed, 1-foot 9-inch cut).	189	16479	A	1	3.89	37.01	46.58	12.52	7.04	4.96	66.19	1.16	8.13	2.4	6,856	12,341
				2		38.51	48.46	13.03	7.33	4.71	68.87	1.21	4.85		7,134	12,841
				3		44.28	55.72		8.43	5.42	79.19	1.39	5.57		8,203	14,765
7 miles from; sec. 25, T. 35 N., R. 16 W.; Todd mine, lowest bed of Mesaverde formation (face of room 9; 340 feet from entry mouth, 2-foot 10-inch bed and cut).	190	16476	A	1	10.97	40.30	42.28	6.45	.81					3.7	6,462	11,632
				2		45.26	47.50	7.24	.91						7,258	13,064
				3		48.79	51.21		.98						7,825	14,085
Same (face of room 10; 330 feet from entry mouth, 3-foot bed and cut).	190	16477	A	1	13.07	39.62	39.72	7.59	.65					5.1	6,194	11,149
				2		45.57	45.70	8.73	.75						7,125	12,825
				3		49.93	50.07		.82						7,806	14,051
Same (composite of samples 16476 and 16477) ...	190	16478	A	1	12.05	39.65	41.27	7.03	.73	5.88	63.43	1.38	21.55	4.4	6,310	11,358
				2		45.08	46.93	7.99	.83	5.16	72.12	1.57	12.33		7,174	12,913
				3		48.99	51.01		.90	5.61	78.38	1.71	13.40		7,797	14,035

Dolores, 11 miles south of; sec. 29, T. 36 N., R. 15 W.; prospect, Dakota formation (near face of entry, 20 feet from mouth, 4-foot 4-inch bed, 2-foot 6½-inch cut).	190	*12551	B	1	10.29	31.81	49.73	8.17	.53	......	......	......	......	.9	......	......
				2	......	35.46	55.43	9.11	.59	......	......	......	......	......	......	......
				3	......	39.01	60.99	......	.65	......	......	......	......	......	......	......
Mancos, 6 miles north of; sec. 30, T. 37 N., R. 13 W.; Haller mine, Dakota formation (in entry, about 50 feet from mine mouth; 3-foot 10-inch bed, 1-foot 9-inch cut).	191	12504	B	1	4.01	28.65	47.56	19.78	.61	......	......	......	......	2.1	6,063	10,913
				2	......	29.85	49.54	20.61	.64	......	......	......	......	......	6,316	11,369
				3	......	37.60	62.40	......	.81	......	......	......	......	......	7,956	14,321
8 miles northeast of; sec. 21, T. 36 N., R. 12 W.; prospect, Dakota formation (in entry, about 20 feet from mouth, 1-foot 8½-inch bed, 1-foot 2-inch cut).	191	12444	B	1	2.60	23.25	41.28	32.87	.45	......	......	......	......	1.4	......	......
				2	......	23.87	42.38	33.75	.46	......	......	......	......	......	......	......
				3	......	36.02	63.98	......	.69	......	......	......	......	......	......	......
OURAY COUNTY.																
Ridgway, 10 miles northeast of; sec. 22, T. 46 N., R. 7 W.; Lou Creek mine, Lou Creek bed (in entry, 600 feet from entry mouth, 20-foot bed, 6-foot cut).	192	12651	B	1	14.15	37.80	40.98	7.07	.58	......	......	......	......	3.5	......	......
				2	......	44.03	47.73	8.24	.68	......	......	......	......	......	......	......
				3	......	47.98	52.02	......	.74	......	......	......	......	......	......	......
RIO BLANCO COUNTY.																
Meeker, 1½ miles northwest of; sec. 15, T. 1 N., R. 94 W.; Black Diamond mine, Lord bed (174 feet northeast of entry mouth, 6-foot 5-inch cut).	192	12776	B	1	10.82	37.25	43.95	7.98	.49	5.52	63.98	1.32	20.71	2.5	6,232	11,218
				2	......	41.77	49.28	8.95	.55	4.84	71.74	1.48	12.44	......	6,988	12,578
				3	......	45.88	54.12	......	.60	5.32	78.79	1.63	13.66	......	7,675	13,815
10 miles northeast of; sec. 10, T. 3 N., R. 93 W.; Cornrike mine (in mine, 30 feet northeast of mine mouth, 7-foot 6-inch bed and cut).	192	12695	B	1	13.88	42.04	41.87	2.21	.28	6.01	63.91	1.28	26.31	3.7	6,262	11,272
				2	......	48.82	48.61	2.57	.33	5.19	74.21	1.49	16.21	......	7,271	13,088
				3	......	50.11	49.89	......	.34	5.33	76.17	1.53	16.63	......	7,463	13,433
2½ miles west of; SW. ¼ sec. 28, T. 1 N., R. 94 W.; Fairfield mine (300 feet from mouth, 6-foot 4-inch cut).	193	12518	B	1	11.02	38.53	44.25	6.20	.85	5.80	64.20	1.32	21.63	4.0	6,314	11,365
				2	......	43.30	49.73	6.97	.96	5.15	72.15	1.48	13.29	......	7,096	12,773
				3	......	46.54	53.46	......	1.03	5.54	77.55	1.59	14.29	......	7,627	13,729
Three-fourths mile from; sec. 22, T. 1 N., R. 94 W.; Meeker mine, Old Pollard bed (about 500 feet northeast of mine mouth, 6-foot 6-inch cut).	193	12426	B	1	12.66	35.92	45.59	5.83	.44	5.69	64.92	1.25	21.87	6.6	6,330	11,394
				2	......	41.13	52.19	6.68	.50	4.90	74.33	1.43	12.16	......	7,248	13,046
				3	......	44.07	55.93	......	.54	5.25	79.65	1.53	13.03	......	7,767	13,980
3 miles west of; sec. 29, T. 1 N., R. 94 W.; Montgomery mine (in mine, 474 feet northeast of mine mouth, 7-foot 6-inch bed and cut).	193	12777	B	1	12.37	38.63	42.87	6.13	.71	5.38	62.61	1.33	23.84	2.0	5,995	10,791
				2	......	44.08	48.92	7.00	.81	4.58	71.45	1.52	14.64	......	6,842	12,315
				3	......	47.40	52.60	......	.87	4.92	76.83	1.63	15.75	......	7,357	13,242
2¼ miles north of; sec. 3, T. 1 N., R. 94 W.; Sulphur Creek mine (in mine, 245 feet north of mine mouth, 5-foot 9-inch bed, 5-foot 7¾-inch cut).	194	12773	B	1	10.41	36.56	44.73	8.30	.59	5.40	63.38	1.36	20.97	2.5	6,257	11,263
				2	......	40.81	49.93	9.26	.66	4.73	70.74	1.52	13.09	......	6,984	12,571
				3	......	44.97	55.03	......	.73	5.21	77.96	1.68	14.42	......	7,696	13,853
12 miles northeast of; sec. 30, T. 2 N., R. 92 W.; Wesson mine (in mine, 258 feet northwest of mine mouth, 22-foot 3½-inch bed, 18-foot 2-inch cut).	194	12705	B	1	14.40	38.42	41.17	6.01	.81	5.83	60.64	1.24	25.47	5.9	5,889	10,600
				2	......	44.88	48.10	7.02	.95	4.94	70.84	1.45	14.80	......	6,880	12,384
				3	......	48.27	51.73	......	1.02	5.31	76.19	1.56	15.92	......	7,399	13,318
IDAHO.																
BOISE COUNTY.																
Horseshoe Bend, 20 miles north of Boise; sec. 3, T. 6 N., R. 2 E.; Henry mine (Jensen level, 140 feet from slope mouth).	195	12703	B	1	10.11	38.24	36.07	15.58	.51	......	......	......	......	5.4	5,797	10,435
				2	......	42.54	40.13	17.33	.57	......	......	......	......	......	6,449	11,608
				3	......	51.46	48.54	......	.69	......	......	......	......	......	7,801	14,042
Same (60 feet from slope mouth)................	195	*12391	B	1	13.09	24.10	24.15	38.66	.36	......	......	......	......	3.8	3,504	6,307
				2	......	27.73	27.79	44.48	.41	......	......	......	......	......	4,032	7,258
				3	......	49.95	50.05	......	.74	......	......	......	......	......	7,262	13,072

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
IDAHO—Continued.																
CASSIA COUNTY.																
Oakley, 22 miles southwest of; sec. 26 (unsurveyed), T. 16 S., R. 20 E.; Worthington mine, Worthington bed (200 feet from slope mouth).	195	12643	B	1	34.46	26.41	21.08	18.05	0.63	......	......	......	......	26.1	3,229	5,812
				2	......	40.30	32.16	27.54	.96	......	......	......	......	......	4,927	8,869
				3	......	55.62	44.38	......	1.32	......	......	......	......	......	6,800	12,240
FREMONT COUNTY.																
Haden, 10 miles southwest of; sec. 25, T. 5 N., R. 43 E.; Brown Bear mine (end of north entry, 950 feet from portal; 5-foot 3-inch bed, 5-foot cut).	196	15115	B	1	11.45	37.24	47.01	4.30	.54	5.94	68.09	1.40	19.73	8.3	6,719	12,094
				2	......	42.06	53.08	4.86	.61	5.27	76.89	1.58	10.79	......	7,588	13,658
				3	......	44,21	55.79	......	.64	5.54	80.82	1.66	11.34	......	7,976	14,357
10 miles southwest of; sec. 6, T. 4 N., R. 44 E.; Horseshoe mine (in entry, 200 feet from portal, 11-foot 1-inch bed, 8-foot 6-inch cut).	196	15116	B	1	7.76	39.68	50.38	2.18	.38	......	......	......	......	4.3	7,155	12,879
				2	......	43.02	54.62	2.36	.41	......	......	......	......	......	7,757	13,963
				3	......	44.06	55.94	......	.42	......	......	......	......	......	7,945	14,301
ILLINOIS.																
MADISON COUNTY.																
Collinsville, 1 mile east of; Cantine No. 3 mine, No. 6 bed (rib, 10 feet from face of west entry 10, off north heading, 3,200 feet northwest of shaft, 7-foot 8½-inch bed, 7-foot 5½-inch cut).	197	10956	A	1	12.94	35.76	41.92	9.38	3.65	......	......	......	......	6.0	6,096	10,973
				2	......	41.07	48.16	10.77	4.19	......	......	......	......	......	7,002	12,604
				3	......	46.02	53.98	......	4.70	......	......	......	......	......	7,846	14,123
Same (face of first stub on east entry 8, off north heading, 4,200 feet north of shaft, 6-foot 10⅞-inch bed, 6-foot 6¾-inch cut).	197	10957	A	1	12.31	37.57	41.09	9.03	3.58	......	......	......	......	5.4	6,175	11,115
				2	......	42.84	46.86	10.30	4.08	......	......	......	......	......	7,042	12,676
				3	......	47.76	52.24	......	4.55	......	......	......	......	......	7,850	14,130
Same (rib, 8 feet from face of east entry 7, on south heading, 2,500 feet southeast of shaft, 7-foot 7¼-inch bed, 7-foot 5⅝-inch cut).	197	10958	A	1	12.81	36.31	41.35	9.53	3.28	......	......	......	......	5.4	6,124	11,023
				2	......	41.64	47.43	10.93	3.76	......	......	......	......	......	7,023	12,641
				3	......	46.75	53.25	......	4.22	......	......	......	......	......	7,885	14,193
Same (composite of samples 10956, 10957, 10958)...	197	10959	A	1	12.70	36.36	41.47	9.47	3.67	5.81	60.91	.99	19.15	5.6	6,105	10,989
				2	......	41.65	47.50	10.85	4.20	5.04	69.77	1.13	9.01	......	6,993	12,587
				3	......	46.72	53.28	......	4.71	5.65	78.26	1.27	10.11	......	7,844	14,119

MONTGOMERY COUNTY.																
Panama, ¼ mile north of; Panama No. 1 mine, No. 6 bed (face of room 1, third south stub, off southeast entry 3, about 2,000 feet from shaft).	197	11352	A	1	13.23	34.45	42.37	9.95	3.57	......	......	......	......	7.4	......	......
				2	......	39.70	48.83	11.47	4.11	......	......	......	......	......	......	......
				3	......	44.85	55.15	......	4.64	......	......	......	......	......	......	......
Same (face of room 4, third north stub, off west entry 6, off north entry, 2,000 feet from shaft).	197	11353	A	1	12.99	32.86	40.33	13.82	4.06	......	......	......	......	7.2	......	......
				2	......	37.77	46.35	15.88	4.67	......	......	......	......	......	......	......
				3	......	44.90	55.10	......	5.55	......	......	......	......	......	......	......
Same (composite of samples 11352 and 11353).....	197	11354	A	1	13.31	33.62	41.34	11.73	3.75	5.19	59.07	.95	19.31	7.3	5,860	10,548
				2	......	38.78	47.69	13.53	4.33	4.28	68.14	1.10	8.62	......	6,760	12,168
				3	......	44.85	55.15	......	5.01	4.95	78.80	1.27	9.97	......	7,818	14,072
SALINE COUNTY.																
Harrisburg, 1 mile south of; O'Gara No. 9 mine, No. 5 bed (between rooms 18 and 19, face of west entry 3, off main south entry, 3,000 feet from mine mouth, 7-foot 5-inch bed, 7-foot 3-inch cut).	198	12794	A	1	7.12	34.55	50.68	7.65	2.23	......	......	......	......	4.6	6,934	12,481
				2	......	37.20	54.56	8.24	2.40	......	......	......	......	......	7,466	13,439
				3	......	40.54	59.46	......	2.62	......	......	......	......	......	8,136	14,645
Same (face of second crosscut in room 11, off west entry 3, off main south entry, 6-foot 7½-inch bed, 6-foot 7-inch cut).	198	12795	A	1	7.02	34.58	51.46	6.94	2.07	......	......	......	......	4.1	7,022	12,640
				2	......	37.19	55.35	7.46	2.23	......	......	......	......	......	7,552	13,594
				3	......	40.19	59.81	......	2.41	......	......	......	......	......	8,161	14,690
VERMILION COUNTY.																
Westville, 2 miles south of; sec. 19, T. 18 N., R. 11 W.; Little Vermilion mine, No. 6 bed ("Run-of-mine" shipped to Pittsburgh station for testing purposes).	199	14682	C	1	16.16	34.09	39.19	10.56	1.74	5.71	58.38	1.25	22.36	3.4	5,796	10,433
				2	......	40.66	46.75	12.59	2.08	4.66	69.63	1.49	9.55	......	6,913	12,443
				3	......	46.52	53.48	......	2.38	5.33	79.66	1.70	10.93	......	7,908	14,234
INDIANA.																
SULLIVAN COUNTY.																
Dugger, 1½ miles southwest of; Vandalia No. 10 mine, No. 4 bed (face of room 2, east entry 6, off north entry 2, off main east entry, 5-foot 5½-inch bed, 5-foot 2¾-inch cut).	199	10960	A	1	13.05	34.30	47.61	5.04	.82	6.07	67.34	1.44	19.29	6.3	6,679	12,022
				2	......	39.45	54.75	5.80	.94	5.31	77.45	1.66	8.84	......	7,682	13,828
				3	......	41.88	58.12	......	1.00	5.64	82.22	1.76	9.38	......	8,155	14,679
Same (face of room 12, off east entry 6, off north entry 2, off main east entry, 5-foot 3½-inch bed, 5-foot ½-inch cut).	199	10961	A	1	13.48	32.51	48.38	5.63	1.09	5.94	66.01	1.49	19.84	6.6	6,549	11,788
				2	......	37.58	55.91	6.51	1.26	5.13	76.29	1.72	9.09	......	7,569	13,624
				3	......	40.20	59.80	......	1.35	5.49	81.60	1.84	9.72	......	8,096	14,573
WARRICK COUNTY.																
Elberfeld, 1 mile south of; Elberfeld mine, No. 5 bed (in new manway, off main west entry, 200 feet north of shaft bottom, 4-foot ½-inch bed and cut).	200	16578	A	1	9.69	38.59	41.04	10.68	4.79	5.39	62.36	1.28	15.50	5.7	6,340	11,412
				2	......	42.73	45.44	11.83	5.30	4.77	69.05	1.42	7.63	......	7,020	12,636
				3	......	48.46	51.54	......	6.01	5.41	78.32	1.61	8.65	......	7,962	14,332
KANSAS.																
CRAWFORD COUNTY.																
Franklin, ½ mile west of; Western No. 16 mine, Weir-Pittsburg bed (2,000 feet southwest of shaft, 35-inch bed and cut).	200	17032	A	1	6.69	33.55	47.94	11.82	5.25	......	......	......	......	4.3	6,728	12,110
				2	......	35.96	51.37	12.67	5.63	......	......	......	......	......	7,210	12,978
				3	......	41.18	58.82	......	6.45	......	......	......	......	......	8,256	14,861

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
COLORADO—Continued.																
LAS ANIMAS COUNTY—continued.																
Primero; secs. 23, 24, 25, and 26, T. 33 S., R. 66 W.; First West Primero mine, Primero bed (taken from same cars as sample 31141).	182	W31142	C	1	1.3	28.6	52.3	17.8	0.60	......	......	......	......	......	6,828	12,290
				2	......	29.0	53.0	18.0	.60	......	......	......	......	......	6,922	12,460
				3	......	35.4	64.6	......	.73	......	......	......	......	......	8,439	15,190
Primero mine, Primero bed (face of room 1 off second blind back entry, 5-foot 10-inch bed and cut).	180	12025	A	1	2.36	31.07	56.65	9.92	.59	5.06	74.54	1.65	8.24	1.6	7,503	13,505
				2	......	31.82	58.02	10.16	.60	4.92	76.34	1.69	6.29	......	7,685	13,833
				3	......	35.42	64.58	......	.67	5.48	84.97	1.88	7.00	......	8,554	15,397
Same (face of first west slope, 1,500 feet from mouth).	180	12027	A	1	3.98	27.96	50.50	17.56	.51	......	......	......	......	3.0	......	......
				2	......	29.12	52.59	18.29	.53	......	......	......	......	......	......	......
				3	......	35.64	64.36	......	.65	......	......	......	......	......	......	......
Starkville; Starkville mine, Engle-Starkville bed (rib of west entry 8, 30 feet outby slant from new entry, 7-foot 2¼-inch bed, 6-foot 9⅜-inch cut).	182	11134	A	1	2.07	29.15	55.56	13.22	.57	4.64	71.77	1.15	8.65	.8	7,139	12,850
				2	......	29.77	56.73	13.50	.58	4.50	73.28	1.17	6.97	......	7,290	13,122
				3	......	34.42	65.58	......	.67	5.20	84.72	1.35	8.06	......	8,428	15,170
Same (south entry 3, near second crosscut off new entry, 2-foot 11½-inch cut).	182	11135	A	1	1.79	28.67	55.33	14.21	.62	4.69	71.76	1.15	7.57	.8	7,074	12,733
				2	......	29.19	56.34	14.47	.63	4.57	73.07	1.17	6.09	......	7,203	12,965
				3	......	34.13	65.87	......	.74	5.34	85.43	1.37	7.12	......	8,422	15,160
Same (entry I-5 between rooms 26 and 27, on pillar, 15,000 feet southwest of mine mouth, 5-foot 9-inch bed and cut).	182	12196	A	1	1.81	31.16	55.49	11.54	.60	......	......	......	......	.7	......	......
				2	......	31.73	56.52	11.75	.61	......	......	......	......	......	......	......
				3	......	35.95	64.05	......	.69	......	......	......	......	......	......	......
Same (face of south entry 1, 1,200 feet southeast of mine mouth, 4-foot 2-inch cut).	182	12197	A	1	2.97	25.89	49.80	21.34	.54	......	......	......	......	1.8	......	......
				2	......	26.68	51.33	21.99	.56	......	......	......	......	......	......	......
				3	......	34.20	65.80	......	.72	......	......	......	......	......	......	......
Same (composite of samples 12196 and 12197).....	183	12198	A	1	2.50	28.85	52.09	16.56	.55	4.79	69.12	1.10	7.88	1.3	6,881	12,386
				2	......	29.59	53.43	16.98	.56	4.63	70.89	1.13	5.81	......	7,057	12,703
				3	......	35.64	64.36	......	.67	5.58	85.39	1.36	7.00	......	8,500	15,300
Tollerburg; Toller mine, Berwind bed; (face of slope, 2,500 feet from shaft bottom, 7-foot bed and cut).	183	13253	A	1	6.31	30.15	49.45	14.09	.65	5.10	67.46	1.31	11.39	5.5	6,747	12,145
				2	......	32.18	52.78	15.04	.69	4.70	72.00	1.40	6.17	......	7,201	12,962
				3	......	37.88	62.12	......	.81	5.53	84.74	1.65	7.27	......	8,476	15,257
Same (face of north entry 5, 3,000 feet from shaft bottom, 7-foot bed and cut).	183	13254	A	1	5.43	33.01	52.93	8.63	.63	5.46	72.98	1.35	10.95	4.6	7,354	13,237
				2	......	34.90	55.97	9.13	.67	5.14	77.17	1.43	6.46	......	7,776	13,997
				3	......	38.41	61.59	......	.74	5.66	84.93	1.57	7.10	......	8,557	15,403

Same (4,400 feet east and 500 feet north of shaft, 1-foot 10-inch bed and cut).	202	12842	B	1	10.76	36.63	41.32	11.29	3.34	......	......	......	......	8.0	......	......
				2	......	41.05	46.30	12.65	3.74	......	......	......	......	......	......	......
				3	......	46.99	53.01	......	4.28	......	......	......	......	......	......	......
Same (2,300 feet east and 2,600 feet north of shaft, 1-foot 10-inch bed and cut).	202	12843	B	1	11.99	35.69	39.56	12.76	3.50	......	......	......	......	9.6	......	......
				2	......	40.55	44.95	14.50	3.98	......	......	......	......	......	......	......
				3	......	47.43	52.57	......	4.66	......	......	......	......	......	......	......
Same (composite of samples 12841, 12842, and 12843).	202	12844	B	1	11.10	35.51	40.69	12.70	3.99	5.30	60.72	1.13	16.16	8.6	6,147	11,065
				2	......	39.95	45.76	14.29	4.49	4.58	68.30	1.27	7.07	......	6,915	12,447
				3	......	46.61	53.39	......	5.24	5.34	79.69	1.48	8.25	......	8,068	14,522
Leavenworth, south edge of; sec. 36, T. 8 S., R. 22 E.; No. 1 mine, Bevier bed (3,200 feet north and 560 feet west of shaft, 1-foot 9-inch bed).	202	12849	B	1	12.60	34.17	40.37	12.86	4.50	......	......	......	......	9.7	......	......
				2	......	39.10	46.19	14.71	5.15	......	......	......	......	......	......	......
				3	......	45.84	54.16	......	6.04	......	......	......	......	......	......	......
Same (160 feet west and 3,100 feet south of shaft, 1-foot 9-inch bed).	202	12850	B	1	11.83	34.47	39.13	14.57	4.40	......	......	......	......	8.9	......	......
				2	......	39.10	44.37	16.53	4.99	......	......	......	......	......	......	......
				3	......	46.84	53.16	......	5.98	......	......	......	......	......	......	......
Same (110 feet east and 3,310 feet north of shaft, 1-foot 10-inch bed).	202	12851	B	1	11.43	36.05	38.79	13.73	4.17	......	......	......	......	8.8	......	......
				2	......	40.70	43.80	15.50	4.71	......	......	......	......	......	......	......
				3	......	48.17	51.83	......	5.57	......	......	......	......	......	......	......
Same (composite of samples 12849, 12850, and 12851).	202	12852	B	1	11.96	35.21	39.13	13.70	4.41	5.31	58.94	1.09	16.55	9.1	5,956	10,721
				2	......	39.99	44.45	15.56	5.01	4.52	66.94	1.24	6.73	......	6,765	12,177
				3	......	47.36	52.64	......	5.93	5.35	79.28	1.47	7.97	......	8,012	14,421
North edge of; sec. 25, T. 8 S., R. 22 E.; No. 3 mine; Leavenworth bed (in mine, 3,400 feet southeast of shaft, 1-foot 10-inch bed and cut).	203	12845	B	1	10.61	37.07	36.16	16.16	5.19	......	......	......	......	7.6	......	......
				2	......	41.47	40.45	18.08	5.81	......	......	......	......	......	......	......
				3	......	50.62	49.38	......	7.09	......	......	......	......	......	......	......
Same (in mine, 3,800 feet southeast of shaft, 1-foot 10-inch bed and cut).	203	12846	B	1	12.64	34.77	33.22	19.37	4.66	......	......	......	......	9.6	......	......
				2	......	39.80	38.03	22.17	5.33	......	......	......	......	......	......	......
				3	......	51.14	48.86	......	6.85	......	......	......	......	......	......	......
Same (in mine, 3,350 feet southeast of shaft, 1-foot 10-inch bed and cut).	203	12847	B	1	13.03	34.15	40.17	12.65	4.56	......	......	......	......	9.8	......	......
				2	......	39.27	46.19	14.54	5.24	......	......	......	......	......	......	......
				3	......	45.95	54.05	......	6.13	......	......	......	......	......	......	......
Same (composite of samples 12845, 12846, and 12847).	203	12848	B	1	12.06	35.42	36.45	16.07	4.77	5.16	56.54	1.07	16.39	9.0	5,675	10,215
				2	......	40.28	41.45	18.27	5.42	4.34	64.29	1.22	6.46	......	6,453	11,615
				3	......	49.28	50.72	......	6.63	5.31	78.66	1.49	7.91	......	7,895	14,211

KENTUCKY.

LETCHER COUNTY.

Flatgap, Va., 1½ miles south of; local mine, Lower Standiford bed (in entry, about 15 feet from mine mouth, 3-foot 2-inch bed).	203	15172	B	1	4.07	35.21	55.69	5.03	1.74	......	......	......	......	2.8	7,725	13,905
				2	......	36.70	58.06	5.24	1.81	......	......	......	......	......	8,053	14,495
				3	......	38.73	61.27	......	1.91	......	......	......	......	......	8,498	15,296
3 miles southwest of; J. H. Mullin mine, Lower Bolling bed (in main entry, 40 feet from mouth, 4-foot 7-inch bed, 4-foot 1-inch cut).	203	15173	B	1	3.97	31.77	53.07	11.19	.97	......	......	......	......	2.6	7,140	12,852
				2	......	33.08	55.27	11.65	1.01	......	......	......	......	......	7,435	13,383
				3	......	37.44	62.56	......	1.14	......	......	......	......	......	8,416	15,149
Jenkins; Consolidation No. 204 mine, Upper Elkhorn bed (face of main heading, 1,700 feet from mine mouth, 7-foot 6½-inch bed, 7-foot 3½-inch cut).	204	14904	B	1	3.91	33.84	54.76	7.49	.51	......	......	......	......	1.9	7,459	13,426
				2	......	35.22	56.99	7.79	.53	......	......	......	......	......	7,763	13,973
				3	......	38.20	61.80	......	.57	......	......	......	......	......	8,419	15,154
Same (face of east heading, 1,700 feet from mine mouth, 8-foot 5-inch bed, 8-foot cut).	204	14905	B	1	3.64	35.81	57.96	2.59	.51	5.39	80.06	1.52	9.93	1.7	7,912	14,242
				2	......	37.16	60.15	2.69	.53	5.18	83.09	1.58	6.93	......	8,211	14,780
				3	......	38.19	61.81	......	.54	5.32	85.38	1.62	7.14	......	8,438	15,188

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
KENTUCKY—Continued.																
LETCHER COUNTY—continued.																
Jenkins, 5 miles northeast of; local mine, Lower Elkhorn bed (face of entry, 50 feet from mine mouth, 3-foot ½-inch bed, 2-foot ½-inch cut).	204	14970	B	1	4.83	33.71	57.73	3.73	0.82	....	....	....	....	3.1	7,690	13,842
				2	....	35.42	60.66	3.92	.86	....	....	....	....	....	8,081	14,546
				3	....	36.87	63.13	....	.90	....	....	....	....	....	8,411	15,140
Same (position and bed same as sample 14970, 1-foot cut).	204	14971	B	1	5.15	28.79	48.17	17.89	.68	....	....	....	....	3.6	6,363	11,453
				2	....	30.35	50.79	18.86	.72	....	....	....	....	....	6,709	12,076
				3	....	37.40	62.60	....	.89	....	....	....	....	....	8,268	14,882
MUHLENBERG COUNTY.																
Central City, ¼ mile south of; Central mine, No. 9 bed (face of main south entry, 5-foot 6-inch bed and cut).	205	13257	A	1	8.11	38.24	47.01	6.64	2.40	....	....	....	....	5.0	....	....
				2	....	41.62	51.15	7.23	2.61	....	....	....	....	....	....	....
				3	....	44.86	55.14	....	2.81	....	....	....	....	....	....	....
Same (face of room 20, off main south blind entry, 5-foot 6-inch bed and cut).	205	13258	A	1	10.33	35.85	44.65	9.17	2.95	....	....	....	....	7.4	....	....
				2	....	39.98	49.79	10.23	3.29	....	....	....	....	....	....	....
				3	....	44.54	55.46	....	3.67	....	....	....	....	....	....	....
Same (room 3, south entry 6, off main west entry, 5-foot 6-inch bed and cut).	205	13259	A	1	7.98	37.78	47.29	6.95	2.50	....	....	....	....	5.1	....	....
				2	....	41.06	51.39	7.55	2.72	....	....	....	....	....	....	....
				3	....	44.41	55.59	....	2.94	....	....	....	....	....	....	....
Same (composite of samples 13257, 13258, and and 13259).	205	13260	A	1	8.73	37.76	45.93	7.58	2.65	5.52	67.65	1.42	15.18	5.8	6,782	12,208
				2	....	41.37	50.33	8.30	2.90	4.98	74.12	1.56	8.14	....	7,430	13,374
				3	....	45.11	54.89	....	3.16	5.43	80.83	1.70	8.88	....	8,102	14,584
Cleaton; Bevier mine, No. 9 bed (face of room 15, off north air course 8, 4,100 feet from shaft, 5-foot 3-inch bed and cut).	205	15339	A	1	7.98	37.79	45.73	8.50	2.75	....	....	....	....	5.1	6,689	12,040
				2	....	41.07	49.69	9.24	2.99	....	....	....	....	....	7,269	13,084
				3	....	45.25	54.75	....	3.29	....	....	....	....	....	8,009	14,416
Same (face of room 21, off north entry 7, 3,800 feet from shaft, 5-foot 6-inch bed and cut).	205	15340	A	1	8.33	37.97	44.53	9.17	3.39	....	....	....	....	5.4	6,579	11,842
				2	....	41.42	48.58	10.00	3.70	....	....	....	....	....	7,177	12,919
				3	....	46.02	53.98	....	4.11	....	....	....	....	....	7,974	14,353
Same (face of south entry 8, 4,500 feet from shaft, 5-foot 3-inch bed and cut).	205	15341	A	1	8.21	36.04	45.13	10.62	3.77	....	....	....	....	5.5	6,467	11,641
				2	....	39.26	49.17	11.57	4.11	....	....	....	....	....	7,045	12,681
				3	....	44.40	55.60	....	4.65	....	....	....	....	....	7,966	14,339

Graham, 2 miles north of; Skibo mine, No. 9 bed (face of west entry 2, off north entry 1, 4,000 feet north of pit mouth, 4-foot 10-inch bed and cut).	206	16674	A	1	8.81	36.15	46.43	8.61	3.55	5.31	65.34	1.47	15.72	5.4	6,612	11,902
				2	....	39.64	50.92	9.44	3.89	4.76	71.65	1.61	8.65	....	7,251	13,052
				3	....	43.77	56.23	....	4.30	5.26	79.12	1.78	9.54	....	8,007	14,413
Same (face of room 2, off east entry 7, 3,600 feet northeast of pit mouth, 4-foot 9-inch bed).	206	16675	A	1	8.21	36.39	45.34	10.06	3.33	5.36	65.22	1.55	14.48	5.1	6,543	11,777
				2	....	39.64	49.40	10.96	3.63	4.85	71.05	1.69	7.82	....	7,128	12,830
				3	....	44.52	55.48	....	4.08	5.45	79.80	1.90	8.77	....	8,005	14,409
OHIO COUNTY.																
McHenry, near; McHenry mine, No. 9 bed (face of room 4, off south entry 3, 9,000 feet from mine mouth, 4-foot 6-inch bed).	207	15102	A	1	9.89	35.94	43.36	10.81	3.64	5.37	62.27	1.33	16.58	7.0	6,329	11,392
				2	....	39.89	48.11	12.00	4.04	4.74	69.11	1.48	8.63	....	7,024	12,643
				3	....	45.33	54.67	....	4.59	5.39	78.54	1.68	9.80	....	7,982	14,368
Same (room 1, off north entry 4, 8,500 feet from mine mouth, 4-foot 6-inch bed).	207	15103	A	1	9.97	36.54	44.93	8.56	2.62	5.49	65.01	1.40	16.92	7.0	6,540	11,772
				2	....	40.58	49.91	9.51	2.91	4.86	72.21	1.55	8.96	....	7,264	13,075
				3	....	44.84	55.16	....	3.22	5.37	79.80	1.71	9.90	....	8,027	14,449
PIKE COUNTY.																
Hellier, 1 mile southeast of; Edgewater mine, Upper Elkhorn bed (sample taken at mine from three loaded railroad cars).	207	12004	B	1	1.94	35.48	59.88	2.70	.57	5.38	81.37	1.42	8.56	.5	8,163	14,693
				2	....	36.18	61.07	2.75	.58	5.26	82.98	1.45	6.98	....	8,325	14,985
				3	....	37.20	62.80	....	.60	5.41	85.33	1.49	7.17	....	8,561	15,410
MISSOURI.																
ADAIR COUNTY.																
Kirksville, ½ mile west of; sec. 8, T. 63 N., R. 15 W.; Star mine, Tebo (?) bed (in mine, 30 feet south of shaft, 1-foot 5½-inch bed).	207	14799	B	1	15.98	38.15	37.18	8.69	4.12	5.90	59.09	.94	21.26	11.0	5,999	10,798
				2	....	45.41	44.25	10.34	4.90	4.90	70.33	1.12	8.41	....	7,140	12,852
				3	....	50.65	49.35	....	5.46	5.46	78.44	1.25	9.39	....	7,963	14,333
Same (in mine, 12 feet northeast of shaft, 1-foot 8-inch bed).	207	14800	B	1	13.94	37.80	38.11	10.15	5.95	5.71	58.76	1.01	18.42	9.4	6,028	10,850
				2	....	43.92	44.29	11.79	6.91	4.83	68.28	1.17	7.02	....	7,005	12,609
				3	....	49.79	50.21	....	7.83	5.48	77.41	1.33	7.95	....	7,942	14,296
AUDRAIN COUNTY.																
Martinsburg, ½ mile west of; sec. 14, T. 50 N., R. 7 W.; No. 1 mine; Mulky bed (long-wall face, 600 feet south of shaft), 2-foot 6-inch bed and cut.)	208	11483	A	1	11.73	37.18	38.00	13.09	5.07	....	....	....	....	10.5	....	....
				2	....	42.12	43.05	14.83	5.74	....	....	....	....	....	....	....
				3	....	49.45	50.55	....	6.74	....	....	....	....	....	....	....
Same (long-wall face, 600 feet southwest of shaft, 2-foot 6-inch cut).	208	11484	A	1	8.71	40.73	39.92	10.64	5.27	....	....	....	....	7.4	....	....
				2	....	44.62	43.72	11.66	5.77	....	....	....	....	....	....	....
				3	....	50.51	49.49	....	6.53	....	....	....	....	....	....	....
Same (face, 800 feet southwest of shaft, 2-foot 6-inch cut).	208	11485	A	1	9.75	39.12	39.37	11.76	4.88	....	....	....	....	8.5	....	....
				2	....	43.34	43.63	13.03	5.41	....	....	....	....	....	....	....
				3	....	49.83	50.17	....	6.22	....	....	....	....	....	....	....
Same (composite of samples 11483, 11484, and 11485).	208	11478	A	1	10.06	38.65	39.67	11.62	5.16	5.43	60.84	.83	16.12	8.8	6,192	11,146
				2	....	42.97	44.11	12.92	5.74	4.79	67.65	.92	7.98	....	6,885	12,393
				3	....	49.35	50.65	....	6.59	5.50	77.69	1.06	9.16	....	7,907	14,233

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
MISSOURI—Continued.																
BARTON COUNTY.																
Mindenmines, 2 miles northwest of; sec. 30, T. 32 N., R. 33 W.; No. 17 mine; Wier-Pittsburg Lower bed (face, 1,000 feet northeast of shaft, 2-foot 10-inch bed and cut).	208	11185	A	1	6.26	30.13	51.51	12.10	5.45	......	......	......	......	4.7	......	......
				2	......	32.14	54.95	12.91	5.81	......	......	......	......	......	......	......
				3	......	36.90	63.10	......	6.67	......	......	......	......	......	......	......
Same (face, 1,000 feet southeast of shaft, 2-foot 10-inch bed and cut).	208	11186	A	1	6.07	32.66	52.22	9.05	4.14	......	......	......	......	4.6	......	......
				2	......	34.77	55.60	9.63	4.41	......	......	......	......	......	......	......
				3	......	38.48	61.52	......	4.88	......	......	......	......	......	......	......
Same (face, 1,500 feet northwest of shaft, 2-foot 10-inch bed and cut).	208	11187	A	1	5.13	31.97	49.74	13.16	5.01	......	......	......	......	3.7	......	......
				2	......	33.70	52.43	13.87	5.28	......	......	......	......	......	......	......
				3	......	39.13	60.87	......	6.13	......	......	......	......	......	......	......
Same (composite of samples 11185, 11186, and 11187).	208	11188	A	1	5.87	30.98	51.67	11.48	5.00	5.07	67.64	1.09	9.72	4.3	6,855	12,339
				2	......	32.91	54.89	12.20	5.31	4.70	71.85	1.16	4.78	......	7,282	13,108
				3	......	37.48	62.52	......	6.05	5.35	81.84	1.32	5.44	......	8,294	14,929
1 mile northeast of; sec. 28, T. 32 N., R. 33 W.; Pullen No. 1 mine, Wier-Pittsburg Lower bed (south face, 600 feet from shaft, 2-foot 6-inch bed and cut).	209	11177	A	1	5.39	32.26	53.89	8.46	3.55	......	......	......	......	4.2	......	......
				2	......	34.10	56.96	8.94	3.75	......	......	......	......	......	......	......
				3	......	37.45	62.55	......	4.12	......	......	......	......	......	......	......
Same (west face, 400 feet from shaft, 2-foot 7-inch bed and cut).	209	11178	A	1	5.42	32.65	52.13	9.80	3.62	......	......	......	......	4.2	......	......
				2	......	34.52	55.12	10.36	3.83	......	......	......	......	......	......	......
				3	......	38.51	61.49	......	4.27	......	......	......	......	......	......	......
Same (northeast face, 600 feet from shaft, 2-foot 6-inch bed and cut).	209	11179	A	1	5.54	32.34	53.40	8.72	3.39	......	......	......	......	4.2	......	......
				2	......	34.24	56.53	9.23	3.59	......	......	......	......	......	......	......
				3	......	37.72	62.28	......	3.96	......	......	......	......	......	......	......
Same (composite of samples 11177, 11178, and 11179)	209	11180	A	1	5.43	32.06	53.56	8.95	3.62	5.38	71.58	1.37	9.10	4.2	7,218	12,992
				2	......	33.90	56.64	9.46	3.83	5.05	75.69	1.45	4.52	......	7,632	13,738
				3	......	37.44	62.56	......	4.23	5.58	83.60	1.60	4.99	......	8,430	15,174
BATES COUNTY.																
Amsterdam, southern part of; sec. 20, T. 41 N., R. 33 W.; No. 1 mine, Mulberry bed (face, 400 feet east of shaft, 2-foot 6-inch bed and cut).	209	11306	A	1	9.82	31.23	42.57	16.38	4.09	......	......	......	......	8.2	......	......
				2	......	34.63	47.21	18.16	4.54	......	......	......	......	......	......	......
				3	......	42.31	57.69	......	5.55	......	......	......	......	......	......	......

Same (face, 400 feet south of shaft, 2-foot 6-inch bed and cut).	209	11307	A	1	8.74	33.13	44.64	13.49	3.64	......	......	......	......	7.2	......	......
				2	......	36.30	48.92	14.78	3.99	......	......	......	......	......	......	......
				3	......	42.59	57.41	......	4.68	......	......	......	......	......	......	......
Same (face, 400 feet southeast of shaft, 2-foot 6-inch bed and cut).	209	11308	A	1	9.13	32.45	44.21	14.21	3.98	......	......	......	......	7.3	......	......
				2	......	35.71	48.65	15.64	4.38	......	......	......	......	......	......	......
				3	......	42.33	57.67	......	5.19	......	......	......	......	......	......	......
Same (composite of samples 11306, 11307, and 11308).	209	11309	A	1	9.19	32.11	44.17	14.53	3.96	5.11	61.48	1.01	13.91	7.6	6,226	11,207
				2	......	35.36	48.64	16.00	4.36	4.50	67.70	1.11	6.33	......	6,856	12,341
				3	......	42.10	57.90	......	5.19	5.36	80.60	1.32	7.53	......	8,162	14,692
Hume, 4 miles east of, 10 miles west of Rich Hill; sec. 4, T. 38 N., R. 33 W.; No. 1 mine, Mulberry bed (face, 900 feet northwest of shaft, 2-foot 6-inch bed and cut).	210	11226	A	1	12.43	30.02	45.84	11.71	1.98	......	......	......	......	9.8	......	......
				2	......	34.28	52.35	13.37	2.26	......	......	......	......	......	......	......
				3	......	39.57	60.43.	......	2.61	......	......	......	......	......	......	......
Same (face 1,100 feet west of shaft)...............	210	11227	A	1	12.84	30.95	46.86	9.35	1.74	......	......	......	......	10.4	......	......
				2	......	35.51	53.76	10.73	2.00	......	......	......	......	......	......	......
				3	......	39.78	60.22	......	2.24	......	......	......	......	......	......	......
Same (face, 700 feet southwest of shaft)...........	210	11228	A	1	11.39	30.95	46.55	11.11	2.52	......	......	......	......	9.5	......	......
				2	......	34.93	52.53	12.54	2.84	......	......	......	......	......	......	......
				3	......	39.94	60.06	......	3.25	......	......	......	......	......	......	......
Same (composite of samples 11226, 11227, and 11228).	210	11229	A	1	12.27	30.36	46.68	10.69	2.08	5.50	63.26	1.20	17.27	9.9	6,275	11,295
				2	......	34.61	53.20	12.19	2.37	4.72	72.11	1.37	7.24	......	7,153	12,875
				3	......	39.41	60.59	......	2.70	5.38	82.12	1.56	8.24	......	8,146	14,663
New Home; sec. 30, T. 39 N., R. 32 W.; New Home No. 1 mine; Lower Rich Hill bed (face, 200 feet northeast of shaft, 5-foot bed and cut).	210	11222	A	1	9.32	33.97	43.90	12.81	3.84	......	......	......	......	7.7	......	......
				2	......	37.46	48.41	14.13	4.23	......	......	......	......	......	......	......
				3	......	43.63	56.37	......	4.93	......	......	......	......	......	......	......
Same (face, 150 feet southeast of shaft, 5-foot bed and cut).	210	11223	A	1	10.05	32.53	43.22	14.20	4.47	......	......	......	......	8.2	......	......
				2	......	36.16	48.05	15.79	4.97	......	......	......	......	......	......	......
				3	......	42.94	57.06	......	5.90	......	......	......	......	......	......	......
Same (face, 200 feet south of shaft, 5-foot bed and cut).	210	11224	A	1	10.63	31.25	41.85	16.27	6.77	......	......	......	......	8.9	......	......
				2	......	34.97	46.83	18.20	7.57	......	......	......	......	......	......	......
				3	......	42.75	57.25	......	9.25	......	......	......	......	......	......	......
Same (composite of samples 11222, 11223, and 11224).	210	11225	A	1	10.01	33.09	42.45	14.45	5.05	5.27	60.29	1.01	13.93	8.3	6,192	11,146
				2	......	36.77	47.17	16.06	5.61	4.62	66.99	1.12	5.60	......	6,881	12,386
				3	......	43.80	56.20	......	6.68	5.50	79.81	1.33	6.68	......	8,197	14,755
Rich Hill, 2 miles northwest of; sec. 36, T. 39 N., R. 32 W.; Fleming Pit No. 1, Lower Rich Hill bed (face on north side of pit, 5-foot bed, 4-foot 10-inch cut).	210	11197	A	1	7.79	35.37	45.61	11.23	4.13	......	......	......	......	6.1	......	......
				2	......	38.36	49.46	12.18	4.48	......	......	......	......	......	......	......
				3	......	43.68	56.32	......	5.10	......	......	......	......	......	......	......
Same (face on east side of pit, 5-foot bed, 4-foot 10-inch cut).	210	11198	A	1	7.97	35.40	43.60	13.03	5.07	......	......	......	......	6.4	......	......
				2	......	38.47	47.37	14.16	5.51	......	......	......	......	......	......	......
				3	......	44.82	55.18	......	6.42	......	......	......	......	......	......	......
Same (face on south side of pit, 5-foot bed, 4-foot 10-inch cut).	210	11199	A	1	7.55	35.05	43.75	13.65	5.91	......	......	......	......	6.1	......	......
				2	......	37.91	47.32	14.77	6.39	......	......	......	......	......	......	......
				3	......	44.48	55.52	......	7.50	......	......	......	......	......	......	......
Same (composite of samples 11197, 11198, and 11199).	210	11200	A	1	7.79	35.51	44.00	12.70	5.16	5.40	63.17	1.00	12.57	6.2	6,524	11,742
				2	......	38.51	47.72	13.77	5.60	4.91	68.51	1.08	6.13	......	7,075	12,735
				3	......	44.66	55.34	......	6.49	5.69	79.45	1.25	7.12	......	8,205	14,769

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
MISSOURI—Continued.																
BARTON COUNTY.																
Mindenmines, 2 miles northwest of; sec. 30, T. 32 N., R. 33 W.; No. 17 mine; Wier-Pittsburg Lower bed (face, 1,000 feet northeast of shaft, 2-foot 10-inch bed and cut).	208	11185	A	1	6.26	30.13	51.51	12.10	5.45	......	......	......	......	4.7	......	......
				2	......	32.14	54.95	12.91	5.81	......	......	......	......	......	......	......
				3	......	36.90	63.10	......	6.67	......	......	......	......	......	......	......
Same (face, 1,000 feet southeast of shaft, 2-foot 10-inch bed and cut).	208	11186	A	1	6.07	32.66	52.22	9.05	4.14	......	......	......	......	4.6	......	......
				2	......	34.77	55.60	9.63	4.41	......	......	......	......	......	......	......
				3	......	38.48	61.52	......	4.88	......	......	......	......	......	......	......
Same (face, 1,500 feet northwest of shaft, 2-foot 10-inch bed and cut).	208	11187	A	1	5.13	31.97	49.74	13.16	5.01	......	......	......	......	3.7	......	......
				2	......	33.70	52.43	13.87	5.28	......	......	......	......	......	......	......
				3	......	39.13	60.87	......	6.13	......	......	......	......	......	......	......
Same (composite of samples 11185, 11186, and 11187).	208	11188	A	1	5.87	30.98	51.67	11.48	5.00	5.07	67.64	1.09	9.72	4.3	6,855	12,339
				2	......	32.91	54.89	12.20	5.31	4.70	71.85	1.16	4.78	......	7,282	13,108
				3	......	37.48	62.52	......	6.05	5.35	81.84	1.32	5.44	......	8,294	14,929
1 mile northeast of; sec. 28, T. 32 N., R. 33 W.; Pullen No. 1 mine, Wier-Pittsburg Lower bed (south face, 600 feet from shaft, 2-foot 6-inch bed and cut).	209	11177	A	1	5.39	32.26	53.89	8.46	3.55	......	......	......	......	4.2	......	......
				2	......	34.10	56.96	8.94	3.75	......	......	......	......	......	......	......
				3	......	37.45	62.55	......	4.12	......	......	......	......	......	......	......
Same (west face, 400 feet from shaft, 2-foot 7-inch bed and cut).	209	11178	A	1	5.42	32.65	52.13	9.80	3.62	......	......	......	......	4.2	......	......
				2	......	34.52	55.12	10.36	3.83	......	......	......	......	......	......	......
				3	......	38.51	61.49	......	4.27	......	......	......	......	......	......	......
Same (northeast face, 600 feet from shaft, 2-foot 6-inch bed and cut).	209	11179	A	1	5.54	32.34	53.40	8.72	3.39	......	......	......	......	4.2	......	......
				2	......	34.24	56.53	9.23	3.59	......	......	......	......	......	......	......
				3	......	37.72	62.28	......	3.96	......	......	......	......	......	......	......
Same (composite of samples 11177, 11178, and 11179)	209	11180	A	1	5.43	32.06	53.56	8.95	3.62	5.38	71.58	1.37	9.10	4.2	7,218	12,992
				2	......	33.90	56.64	9.46	3.83	5.06	75.69	1.45	4.52	......	7,632	13,738
				3	......	37.44	62.56	......	4.23	5.58	83.60	1.60	4.99	......	8,430	15,174
BATES COUNTY.																
Amsterdam, southern part of; sec. 20, T. 41 N., R. 33 W.; No. 1 mine, Mulberry bed (face, 400 feet east of shaft, 2-foot 6-inch bed and cut).	209	11306	A	1	9.82	31.23	42.57	16.38	4.09	......	......	......	......	8.2	......	......
				2	......	34.63	47.21	18.16	4.54	......	......	......	......	......	......	......
				3	......	42.31	57.69	......	5.55	......	......	......	......	......	......	......

Same (face, 400 feet south of shaft, 2-foot 6-inch bed and cut).	209	11307	A	1	8.74	33.13	44.64	13.49	3.64	....	....	....	....	7.2	....	....
				2	....	36.30	48.92	14.78	3.99	....	....	....	....	....	....	....
				3	....	42.59	57.41	....	4.68	....	....	....	....	....	....	....
Same (face, 400 feet southeast of shaft, 2-foot 6-inch bed and cut).	209	11308	A	1	9.13	32.45	44.21	14.21	3.98	....	....	....	....	7.3	....	....
				2	....	35.71	48.65	15.64	4.38	....	....	....	....	....	....	....
				3	....	42.33	57.67	....	5.19	....	....	....	....	....	....	....
Same (composite of samples 11306, 11307, and 11308).	209	11309	A	1	9.19	32.11	44.17	14.53	3.96	5.11	61.48	1.01	13.91	7.6	6,226	11,207
				2	....	35.36	48.64	16.00	4.36	4.50	67.70	1.11	6.33	....	6,856	12,341
				3	....	42.10	57.90	....	5.19	5.36	80.60	1.32	7.53	....	8,162	14,692
Hume, 4 miles east of, 10 miles west of Rich Hill; sec. 4, T. 38 N., R. 33 W.; No. 1 mine, Mulberry bed (face, 900 feet northwest of shaft, 2-foot 6-inch bed and cut).	210	11226	A	1	12.43	30.02	45.84	11.71	1.98	....	....	....	....	9.8	....	....
				2	....	34.28	52.35	13.37	2.26	....	....	....	....	....	....	....
				3	....	39.57	60.43.	....	2.61	....	....	....	....	....	....	....
Same (face 1,100 feet west of shaft)...............	210	11227	A	1	12.84	30.95	46.86	9.35	1.74	....	....	....	....	10.4	....	....
				2	....	35.51	53.76	10.73	2.00	....	....	....	....	....	....	....
				3	....	39.78	60.22	....	2.24	....	....	....	....	....	....	....
Same (face, 700 feet southwest of shaft)...........	210	11228	A	1	11.39	30.95	46.55	11.11	2.52	....	....	....	....	9.5	....	....
				2	....	34.93	52.53	12.54	2.84	....	....	....	....	....	....	....
				3	....	39.94	60.06	....	3.25	....	....	....	....	....	....	....
Same (composite of samples 11226, 11227, and 11228).	210	11229	A	1	12.27	30.36	46.68	10.69	2.08	5.50	63.26	1.20	17.27	9.9	6,275	11,295
				2	....	34.61	53.20	12.19	2.37	4.72	72.11	1.37	7.24	....	7,153	12,875
				3	....	39.41	60.59	....	2.70	5.38	82.12	1.56	8.24	....	8,146	14,663
New Home; sec. 30, T. 39 N., R. 32 W.; New Home No. 1 mine; Lower Rich Hill bed (face, 200 feet northeast of shaft, 5-foot bed and cut).	210	11222	A	1	9.32	33.97	43.90	12.81	3.84	....	....	....	....	7.7	....	....
				2	....	37.46	48.41	14.13	4.23	....	....	....	....	....	....	....
				3	....	43.63	56.37	....	4.93	....	....	....	....	....	....	....
Same (face, 150 feet southeast of shaft, 5-foot bed and cut).	210	11223	A	1	10.05	32.53	43.22	14.20	4.47	....	....	....	....	8.2	....	....
				2	....	36.16	48.05	15.79	4.97	....	....	....	....	....	....	....
				3	....	42.94	57.06	....	5.90	....	....	....	....	....	....	....
Same (face, 200 feet south of shaft, 5-foot bed and cut).	210	11224	A	1	10.63	31.25	41.85	16.27	6.77	....	....	....	....	8.9	....	....
				2	....	34.97	46.83	18.20	7.57	....	....	....	....	....	....	....
				3	....	42.75	57.25	....	9.25	....	....	....	....	....	....	....
Same (composite of samples 11222, 11223, and 11224).	210	11225	A	1	10.01	33.09	42.45	14.45	5.05	5.27	60.29	1.01	13.93	8.3	6,192	11,146
				2	....	36.77	47.17	16.06	5.61	4.62	66.99	1.12	5.60	....	6,881	12,386
				3	....	43.80	56.20	....	6.68	5.50	79.81	1.33	6.68	....	8,197	14,755
Rich Hill, 2 miles northwest of; sec. 36, T. 39 N., R. 32 W.; Fleming Pit No. 1, Lower Rich Hill bed (face on north side of pit, 5-foot bed, 4-foot 10-inch cut).	210	11197	A	1	7.79	35.37	45.61	11.23	4.13	....	....	....	....	6.1	....	....
				2	....	38.36	49.46	12.18	4.48	....	....	....	....	....	....	....
				3	....	43.68	56.32	....	5.10	....	....	....	....	....	....	....
Same (face on east side of pit, 5-foot bed, 4-foot 10-inch cut).	210	11198	A	1	7.97	35.40	43.60	13.03	5.07	....	....	....	....	6.4	....	....
				2	....	38.47	47.37	14.16	5.51	....	....	....	....	....	....	....
				3	....	44.82	55.18	....	6.42	....	....	....	....	....	....	....
Same (face on south side of pit, 5-foot bed, 4-foot 10-inch cut).	210	11199	A	1	7.55	35.05	43.75	13.65	5.91	....	....	....	....	6.1	....	....
				2	....	37.91	47.32	14.77	6.39	....	....	....	....	....	....	....
				3	....	44.48	55.52	....	7.50	....	....	....	....	....	....	....
Same (composite of samples 11197, 11198, and 11199).	210	11200	A	1	7.79	35.51	44.00	12.70	5.16	5.40	63.17	1.00	12.57	6.2	6,524	11,742
				2	....	38.51	47.72	13.77	5.60	4.91	68.51	1.08	6.13	....	7,075	12,735
				3	....	44.66	55.34	....	6.49	5.69	79.45	1.25	7.12	....	8,205	14,769

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
MISSOURI—Continued.																
BATES COUNTY—continued.																
Rich Hill, 2 miles south of; sec. 17, T. 38 N., R. 31 W.; Ritchie Pit No. 1, Lower Rich Hill bed (face on north side pit, 4-foot 11-inch bed, 4-foot 8-inch cut).	211	11193	A	1	9.72	33.99	42.49	13.80	5.20	......	......	......	......	8.4	......	......
				2	......	37.65	47.06	15.29	5.76	......	......	......	......	......	......	......
				3	......	44.45	55.55	......	6.80	......	......	......	......	......	......	......
Same (face on south side pit, 4-foot 11-inch bed, 4-foot 8-inch cut).	211	11194	A	1	8.54	34.88	40.51	16.07	4.32	......	......	......	......	7.3	......	......
				2	......	38.14	44.29	17.57	4.72	......	......	......	......	......	......	......
				3	......	46.27	53.73	......	5.73	......	......	......	......	......	......	......
Same (composite of samples 11193 and 11194)	211	11195	A	1	9.20	34.34	41.28	15.18	4.88	5.33	60.22	1.11	13.28	7.9	6,195	11,151
				2	......	37.82	45.46	16.72	5.37	4.75	66.32	1.22	5.62	......	6,823	12,281
				3	......	45.41	54.59	......	6.45	5.70	79.64	1.46	6.75	......	8,193	14,747
2 miles south of; sec. 17, T. 38 N., R. 31 W.; Ritchie Pit No. 2, Lower Rich Hill bed (face on south side pit, 2-foot cut).	211	*11196	A	1	35.97	22.54	26.85	14.64	.81	5.93	33.23	.70	44.69	30.1	2,920	5,256
				2	......	35.20	41.94	22.86	1.27	3.01	51.90	1.09	19.87	......	4,560	8,208
				3	......	45.63	54.37	......	1.65	3.90	67.28	1.41	25.76	......	5,911	10,640
BOONE COUNTY.																
Columbia, 3½ miles northeast of; sec. 4, T. 48 N., R. 12 W.; No. 1 mine (face, 110 feet north of shaft, 3-foot bed and cut).	211	11476	A	1	11.16	34.95	43.32	10.57	3.71	5.23	62.92	.95	16.62	9.8	6,293	11,327
				2	......	39.34	48.76	11.90	4.18	4.49	70.82	1.07	7.54	......	7,083	12,749
				3	......	44.65	55.35	......	4.74	5.10	80.39	1.21	8.56	......	8,040	14,472
Same (face, 50 feet west of shaft, 3-foot bed and cut)	211	11477	A	1	9.41	34.91	45.34	10.34	4.08	5.42	63.47	.97	15.72	8.0	6,466	11,639
				2	......	38.54	50.05	11.41	4.50	4.82	70.06	1.07	8.14	......	7,138	12,848
				3	......	43.50	56.50	......	5.08	5.44	79.08	1.21	9.19	......	8,057	14,503
3½ miles northeast of; sec. 4, T. 48 N., R. 12 W.; No. 2 mine (face, 50 feet west of shaft, 3-foot bed and cut).	211	11475	A	1	10.48	35.31	44.16	10.05	4.49	5.49	62.81	.95	16.21	9.0	6,365	11,457
				2	......	39.44	49.33	11.23	5.02	4.84	70.17	1.06	7.68	......	7,110	12,798
				3	......	44.43	55.57	......	5.66	5.45	79.05	1.19	8.65	......	8,009	14,416
4½ miles north of; sec. 11, T. 49 N., R. 12 W.; Prather No. 1 mine (face, 600 feet southwest of shaft, 3-foot 6-inch cut).	212	11479	A	1	12.29	31.43	40.33	15.95	6.36	......	......	......	......	11.0	......	......
				2	......	35.83	45.99	18.18	7.25	......	......	......	......	......	......	......
				3	......	43.79	56.21	......	8.86	......	......	......	......	......	......	......
Same (face, 600 feet west of shaft, 3-foot 6-inch cut)	212	11480	A	1	9.82	34.81	42.85	12.52	4.72	......	......	......	......	8.4	......	......
				2	......	38.60	47.52	13.88	5.23	......	......	......	......	......	......	......
				3	......	44.82	55.18	......	6.07	......	......	......	......	......	......	......

Same (face, 800 feet east of shaft, 3-foot 6-inch cut)	211	11481	A	1	9.82	35.13	43.94	11.11	3.75	......	......	......	......	8.4	......	......
				2	......	38.96	48.72	12.32	4.16	......	......	......	......	......	......	......
				3	......	44.43	55.57	......	4.74	......	......	......	......	......	......	......
Same (composite of samples 11479, 11480, and 11481).	211	11482	A	1	10.76	33.63	42.40	13.21	5.06	5.27	60.15	.92	15.39	9.3	6,023	10,841
				2	......	37.69	47.51	14.80	5.67	4.56	67.40	1.03	6.54	......	6,749	12,148
				3	......	44.24	55.76	......	6.65	5.35	79.11	1.21	7.68	......	7,921	14,258
CALLAWAY COUNTY.																
Fulton, 2 miles southwest of; sec. 18, T. 47 N., R. 9 W.; No. 1 mine, Bevier bed (face, 1,000 feet east of shaft, 2-foot 6-inch bed and cut).	212	11501	A	1	10.95	33.45	45.24	10.36	3.69	......	......	......	......	9.5	......	......
				2	......	37.56	50.81	11.63	4.14	......	......	......	......	......	......	......
				3	......	42.50	57.50	......	4.68	......	......	......	......	......	......	......
Same (face, 600 feet northeast of shaft, 2-foot 6-inch bed and cut).	212	11502	A	1	10.23	32.18	46.44	11.15	4.23	......	......	......	......	8.6	......	......
				2	......	35.85	51.73	12.42	4.71	......	......	......	......	......	......	......
				3	......	40.93	59.07	......	5.38	......	......	......	......	......	......	......
Same (face, 600 feet southwest of shaft, 2-foot 6-inch bed and cut).	212	11503	A	1	11.15	33.42	45.51	9.92	3.91	......	......	......	......	9.8	......	......
				2	......	37.61	51.23	11.16	4.40	......	......	......	......	......	......	......
				3	......	42.33	57.67	......	4.95	......	......	......	......	......	......	......
Same (composite of samples 11501, 11502, and 11503).	212	11504	A	1	10.77	32.82	46.04	10.37	4.00	5.37	63.72	.90	15.64	9.3	6,389	11,500
				2	......	36.78	51.60	11.62	4.48	4.67	71.41	1.01	6.81	......	7,160	12,888
				3	......	41.62	58.38	......	5.07	5.28	80.80	1.14	7.71	......	8,102	14,584
HARRISON COUNTY.																
Cainsville; sec. 13, T. 65 N., R. 26 W.; Cainsville mine, Cainsville bed; main west air course, 600 feet west and 50 feet north of shaft, 3-foot 10½-inch bed.	212	12679	B	1	12.99	39.71	35.38	11.92	5.24	......	......	......	......	7.8	5,864	10,555
				2	......	45.64	40.66	13.70	6.02	......	......	......	......	......	6,739	12,130
				3	......	52.88	47.12	......	6.98	......	......	......	......	......	7,808	14,054
Same (south entry 2, off main east entry, 150 feet east and 350 feet south of shaft, 3-foot 9½-inch bed).	213	12680	B	1	11.70	38.79	38.80	10.71	5.13	......	......	......	......	8.8	6,124	11,023
				2	......	43.93	43.94	12.13	5.81	......	......	......	......	......	6,935	12,483
				3	......	49.99	50.01	......	6.61	......	......	......	......	......	7,892	14,206
Same (south entry 2, off main west entry, 400 feet southwest of shaft, 3-foot 9½-inch bed).	213	12681	B	1	13.12	38.88	37.32	10.68	4.78	......	......	......	......	10.1	6,046	10,883
				2	......	44.75	42.96	12.29	5.50	......	......	......	......	......	6,959	12,526
				3	......	51.02	48.98	......	6.27	......	......	......	......	......	7,934	14,281
Melbourne, ½ mile east of; sec. 25, T. 62 N., R. 26 W.; Trenton No. 1 mine, Lexington bed (face, 90 feet south of shaft, 3-foot 3-inch bed, 2-foot 10-inch cut).	213	11374	A	1	15.16	37.32	40.54	6.98	2.86	......	......	......	......	11.6	......	......
				2	......	43.99	47.78	8.23	3.37	......	......	......	......	......	......	......
				3	......	47.94	52.06	......	3.67	......	......	......	......	......	......	......
Same (face, 85 feet northeast of shaft, 3-foot 3-inch bed, 2-foot 10-inch cut).	213	11375	A	1	15.05	37.35	40.19	7.41	3.33	......	......	......	......	12.1	......	......
				2	......	43.97	47.31	8.72	3.92	......	......	......	......	......	......	......
				3	......	48.17	51.83	......	4.29	......	......	......	......	......	......	......
Same (face, 30 feet north of shaft, 3-foot 3-inch bed, 2-foot 10-inch cut).	213	11376	A	1	15.77	35.83	42.86	5.54	2.75	......	......	......	......	12.4	......	......
				2	......	42.54	50.88	6.58	3.26	......	......	......	......	......	......	......
				3	......	45.53	54.47	......	3.49	......	......	......	......	......	......	......
Same (composite of samples 11374, 11375, and 11376)	213	11377	A	1	15.34	37.14	40.74	6.78	3.03	5.89	61.18	1.10	22.02	12.0	6,166	11,099
				2	......	43.87	48.12	8.01	3.58	4.96	72.27	1.30	9.89	......	7,283	13,109
				3	......	47.69	52.31	......	3.89	5.38	78.56	1.41	10.76	......	7,917	14,251

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
MISSOURI—Continued.																
HENRY COUNTY.																
Calhoun, 2¼ miles west of; sec. 25, T. 34 N., R. 26 W.; Parks No. 1 mine, Tebo bed (face, 700 feet southeast of mine mouth, 2-foot 8-inch bed, 2-foot 7-inch cut).	213	11314	A	1	10.58	36.04	41.31	12.07	3.73	......	......	......	......	8.6	......	......
				2	......	40.30	46.20	13.50	4.17	......	......	......	......	......	......	......
				3	......	46.59	53.41	......	4.82	......	......	......	......	......	......	......
Same (face, 700 feet southwest of mine mouth, 2-foot 8-inch bed, 2-foot 7-inch cut).	213	11315	A	1	10.55	38.91	39.99	10.55	3.51	......	......	......	......	7.9	......	......
				2	......	43.50	44.71	11.79	3.92	......	......	......	......	......	......	......
				3	......	49.32	50.68	......	4.44	......	......	......	......	......	......	......
Same (face, 800 feet west of mine mouth, 2-foot 8-inch bed, 2-foot 7-inch cut).	213	11316	A	1	10.90	36.95	40.29	11.86	3.50	......	......	......	......	9.5	......	......
				2	......	41.47	45.22	13.31	3.93	......	......	......	......	......	......	......
				3	......	47.84	52.16	......	4.53	......	......	......	......	......	......	......
Same (composite of samples 11314, 11315, and 11316)	213	11317	A	1	10.60	37.24	40.65	11.51	3.58	5.41	61.80	0.90	16.80	8.7	6,249	11,248
				2	......	41.66	45.46	12.88	4.00	4.73	69.13	1.01	8.25	......	6,990	12,582
				3	......	47.82	52.18	......	4.59	5.43	79.35	1.16	9.47	......	8,023	14,441
Clinton, 3½ miles northwest of; sec. 28, T. 42 N., R. 26 W.; Lane No. 1 mine, Tebo bed (face, 210 feet northwest of entry mouth, 30-inch bed and cut).	214	11248	A	1	8.54	38.02	40.87	12.57	4.22	......	......	......	......	6.4	......	......
				2	......	41.57	44.69	13.74	4.61	......	......	......	......	......	......	......
				3	......	48.19	51.81	......	5.34	......	......	......	......	......	......	......
Same (face, 300 feet northeast of entry mouth, 2-foot 6-inch bed and cut).	214	11249	A	1	8.38	36.88	40.54	14.20	3.71	......	......	......	......	5.3	......	......
				2	......	40.25	44.25	15.50	4.05	......	......	......	......	......	......	......
				3	......	47.63	52.37	......	4.79	......	......	......	......	......	......	......
Same (face, 230 feet north of entry mouth, 2-foot 6-inch bed and cut).	214	11250	A	1	10.73	35.35	41.20	12.72	3.74	......	......	......	......	7.6	......	......
				2	......	39.60	46.15	14.25	4.19	......	......	......	......	......	......	......
				3	......	46.18	53.82	......	4.89	......	......	......	......	......	......	......
Same (composite of samples 11248, 11249 and 11250)	214	11251	A	1	9.13	37.43	40.43	13.01	3.81	5.37	62.50	.90	14.41	6.4	6,365	11,457
				2	......	41.19	44.49	14.32	4.19	4.80	68.78	.99	6.92	......	7,005	12,609
				3	......	48.07	51.93	......	4.89	5.60	80.27	1.16	8.08	......	8,176	14,717
1 mile north of; sec. 34, T. 42 N., R. 26 W.; Neil No. 1 mine (face, 200 feet southwest of shaft, 2-foot 6-inch bed, 2-foot 4-inch cut).	214	11302	A	1	8.15	36.57	38.85	16.43	4.76	......	......	......	......	6.8	......	......
				2	......	39.81	42.30	17.89	5.18	......	......	......	......	......	......	......
				3	......	48.48	51.52	......	6.31	......	......	......	......	......	......	......
Same (face, 100 feet northwest of shaft, 2-foot 6-inch bed, 2-foot 4-inch cut).	214	11303	A	1	10.93	35.07	39.58	14.42	3.87	......	......	......	......	9.3	......	......
				2	......	39.37	44.44	16.19	4.34	......	......	......	......	......	......	......
				3	......	46.98	53.02	......	5.18	......	......	......	......	......	......	......
Same (face, 75 feet east of shaft, 2-foot 6-inch bed, 2-foot 4-inch cut).	214	11304	A	1	18.78	32.09	37.63	11.50	2.34	......	......	......	......	15.9	......	......
				2	......	39.51	46.33	14.16	2.86	......	......	......	......	......	......	......
				3	......	46.08	53.97	......	3.36	......	......	......	......	......	......	......

Same (composite of samples 11302, 11303, and 11304).	214	11305	A	1	12.57	34.68	38.77	13.98	3.65	5.49	58.38	.96	17.54	10.7	5,951	10,712
				2	......	39.67	44.34	15.99	4.17	4.68	66.78	1.10	7.28	......	6,807	12,253
				3	......	47.22	52.78	......	4.96	5.57	79.49	1.31	8.67	......	8,102	14,584
2 miles east of; sec. 7, T. 41 N., R. 26 W.; Pharis No. 1 mine, Jordan bed (face, 100 feet west of shaft, 22-inch bed, 20-inch cut).	215	11370	A	1	12.29	33.26	41.59	12.86	2.43	......	......	......	......	10.1	......	......
				2	......	37.92	47.42	14.66	2.77	......	......	......	......	......	......	......
				3	......	44.43	55.57	......	3.25	......	......	......	......	......	......	......
Same (face, 100 feet south of shaft, 22-inch bed, 20-inch cut).	215	11371	A	1	13.07	34.34	44.28	8.31	2.06	......	......	......	......	10.4	......	......
				2	......	39.50	50.94	9.56	2.37	......	......	......	......	......	......	......
				3	......	43.68	56.32	......	2.62	......	......	......	......	......	......	......
Same (face, 50 feet east of shaft, 22-inch bed, 20-inch cut).	215	11372	A	1	12.82	33.32	43.06	10.80	3.00	......	......	......	......	10.4	......	......
				2	......	38.22	49.39	12.39	3.44	......	......	......	......	......	......	......
				3	......	43.62	56.38	......	3.93	......	......	......	......	......	......	......
Same (composite of samples 11370, 11371, and 11372).	215	11373	A	1	12.76	33.05	43.64	10.55	2.57	5.53	61.87	1.12	18.36	10.3	6,205	11,169
				2	......	37.89	50.02	12.09	2.95	4.71	70.92	1.28	8.05	......	7,113	12,803
				3	......	43.10	56.90	......	3.36	5.36	80.67	1.46	9.15	......	8,091	14,564
3 miles southeast of; sec. 25, T. 41 N., R. 26 W.; Sheldon No. 1 mine, Jordan bed (face, 80 feet southwest of shaft, 2-foot 2-inch bed and cut).	215	11262	A	1	9.56	34.72	43.11	12.61	5.67	......	......	......	......	7.9	......	......
				2	......	38.39	47.67	13.94	6.27	......	......	......	......	......	......	......
				3	......	44.61	55.39	......	7.29	......	......	......	......	......	......	......
Same (face, 110 feet south of shaft, 2-foot 2-inch bed and cut).	215	11263	A	1	10.64	33.64	43.77	11.95	5.37	......	......	......	......	8.9	......	......
				2	......	37.65	48.98	13.37	6.01	......	......	......	......	......	......	......
				3	......	43.46	56.54	......	6.94	......	......	......	......	......	......	......
Same (face, 110 feet southeast of shaft, 2-foot 2-inch bed and cut).	215	11264	A	1	9.72	36.62	43.42	10.24	5.13	......	......	......	......	8.1	......	......
				2	......	40.56	48.10	11.34	5.68	......	......	......	......	......	......	......
				3	......	45.75	54.25	......	6.41	......	......	......	......	......	......	......
Same (composite of samples 11262, 11263, and 11264).	215	11265	A	1	9.90	35.03	43.31	11.76	5.38	5.39	61.99	1.06	14.42	8.3	6,356	11,441
				2	......	38.88	48.07	13.05	5.97	4.76	68.80	1.18	6.24	......	7,055	12,699
				3	......	44.72	55.28	......	6.87	5.47	79.13	1.36	7.17	......	8,114	14,605
Deepwater, in eastern part of; sec. 14, T. 40 N., R. 26 W.; Dickey No. 1 pit, Jordan bed (face, on north side of pit, 2-foot 2-inch bed, 2-foot cut).	215	11310	A	1	9.96	33.76	46.55	9.74	3.49	......	......	......	......	8.3	......	......
				2	......	37.49	51.69	10.82	3.88	......	......	......	......	......	......	......
				3	......	42.04	57.96	......	4.35	......	......	......	......	......	......	......
Same (face, on east side of pit, 2-foot 2-inch bed, 2-foot cut).	215	11311	A	1	9.82	33.89	46.17	10.12	3.46	......	......	......	......	8.4	......	......
				2	......	37.58	51.20	11.22	3.84	......	......	......	......	......	......	......
				3	......	42.33	57.67	......	4.33	......	......	......	......	......	......	......
Same (face, on west side of pit, 2-foot 2-inch bed, 2-foot cut).	215	11312	A	1	9.55	34.10	45.83	10.52	3.90	......	......	......	......	7.7	......	......
				2	......	37.70	50.67	11.63	4.31	......	......	......	......	......	......	......
				3	......	42.66	57.34	......	4.88	......	......	......	......	......	......	......
Same (composite of samples 11310, 11311, and 11312).	216	11313	A	1	9.70	33.78	46.26	10.26	3.63	5.38	65.19	1.03	14.51	8.1	6,566	11,819
				2	......	37.41	51.23	11.36	4.02	4.76	72.19	1.14	6.53	......	7,271	13,088
				3	......	42.21	57.79	......	4.54	5.37	81.44	1.29	7.36	......	8,203	14,765
¾ mile east of; sec. 13, T. 40 N., R. 26 W.; Hurst No. 1 mine, Jordan bed (face, 100 feet northeast of shaft, 3-foot 4-inch bed and cut).	216	11252	A	1	9.31	36.38	41.57	12.74	5.07	......	......	......	......	7.3	......	......
				2	......	40.12	45.83	14.05	5.59	......	......	......	......	......	......	......
				3	......	46.68	53.32	......	6.50	......	......	......	......	......	......	......
Same (face, 350 feet west of shaft, 3-foot 4-inch bed and cut).	216	11253	A	1	11.55	33.95	41.80	12.70	4.01	......	......	......	......	10.0	......	......
				2	......	38.38	47.26	14.36	4.53	......	......	......	......	......	......	......
				3	......	44.82	55.18	......	5.29	......	......	......	......	......	......	......
Same (face, 450 feet northeast of shaft, 3-foot 4-inch bed and cut).	216	11254	A	1	9.52	34.52	41.89	14.07	3.91	......	......	......	......	7.9	......	......
				2	......	38.15	46.30	15.55	4.32	......	......	......	......	......	......	......
				3	......	45.17	54.83	......	5.12	......	......	......	......	......	......	......
Same (composite of samples 11252, 11253, and 11254).	216	11255	A	1	10.10	34.83	41.76	13.31	4.32	5.18	60.94	.99	15.26	8.4	6,199	11,158
				2	......	38.74	46.46	14.80	4.81	4.52	67.78	1.10	6.99	......	6,895	12,411
				3	......	45.47	54.53	......	5.65	5.31	79.55	1.29	8.20	......	8,093	14,567

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
MISSOURI—Continued.																
HENRY COUNTY—continued.																
Lewis, ½ mile north of; sec. 9, T. 42 N., R. 25 W.; Pigg No. 1 mine, Tebo bed (face, 1,300 feet west of shaft).	216	11267	A	1	11.91	33.31	39.98	14.80	4.86	....	....	....	....	10.3	....	....
				2	....	37.81	45.39	16.80	5.52	....	....	....	....	....	....	....
				3	....	45.44	54.56	....	6.63	....	....	....	....	....	....	....
Same (face, 1,300 feet southwest of shaft, 2-foot 6-inch bed and cut).	216	11268	A	1	11.08	36.28	39.96	12.68	3.82	....	....	....	....	9.4	....	....
				2	....	40.80	44.94	14.26	4.30	....	....	....	....	....	....	....
				3	....	47.59	52.41	....	5.02	....	....	....	....	....	....	....
Same (face, 1,400 feet southwest of shaft, 2-foot 6-inch bed and cut).	216	11269	A	1	11.04	38.03	40.56	10.37	3.39	....	....	....	....	9.3	....	....
				2	....	42.75	45.59	11.66	3.81	....	....	....	....	....	....	....
				3	....	48.39	51.61	....	4.31	....	....	....	....	....	....	....
Same (composite of samples 11267, 11268, and 11269, 2-foot 6-inch bed and cut).	216	11270	A	1	11.44	34.67	41.13	12.76	4.25	5.53	59.88	0.96	16.63	9.6	6,117	11,011
				2	....	39.15	46.44	14.41	4.80	4.81	67.62	1.07	7.29	....	6,907	12,433
				3	....	45.74	54.26	....	5.61	5.62	79.01	1.25	8.51	....	8,070	14,526
LINN COUNTY.																
Brookfield, 1½ miles east of; sec. 20, T. 57 N., R. 19 W.; Crandall No. 1 mine, Tebo bed (face, 750 feet southeast of shaft, 2-foot 5-inch bed, 2-foot 2-inch cut).	217	11421	A	1	14.78	36.64	38.23	10.35	4.62	....	....	....	....	12.7	....	....
				2	....	42.99	44.87	12.14	5.42	....	....	....	....	....	....	....
				3	....	48.93	51.07	....	6.17	....	....	....	....	....	....	....
Same (face, 750 feet southwest of shaft, 2-foot 5-inch bed, 2-foot 2-inch cut).	217	11422	A	1	14.46	36.99	41.19	7.36	4.28	....	....	....	....	12.2	....	....
				2	....	43.24	48.16	8.60	5.00	....	....	....	....	....	....	....
				3	....	47.31	52.69	....	5.47	....	....	....	....	....	....	....
Same (face, 800 feet east of shaft, 2-foot 5-inch bed, 2-foot 2-inch cut).	217	11423	A	1	15.81	36.18	41.45	6.56	3.78	....	....	....	....	13.7	....	....
				2	....	42.97	49.24	7.79	4.49	....	....	....	....	....	....	....
				3	....	46.60	53.40	....	4.87	....	....	....	....	....	....	....
Same (composite of samples 11421, 11422, and 11423).	217	11424	A	1	15.09	36.05	40.71	8.15	4.21	5.81	60.67	.99	20.17	12.9	6,100	10,980
				2	....	42.46	47.94	9.60	4.96	4.86	71.45	1.17	7.96	....	7,184	12,931
				3	....	46.97	53.03	....	5.49	5.38	79.04	1.29	8.80	....	7,947	14,305

3 miles southeast of; sec. 16, T. 57 N., R. 19 W.; Walker No. 1 mine, Tebo bed (face, 250 feet southwest of shaft, 2-foot 6-inch bed, 2-foot 2-inch cut).	217	11413	A	1	14.14	36.74	40.36	8.76	4.36	......	......	......	......	11.8	......	......
				2	......	42.79	47.01	10.20	5.08	......	......	......	......	......	......	......
				3	......	47.65	52.35	......	5.66	......	......	......	......	......	......	......
Same (face, 200 feet northeast of shaft, 2-foot 6-inch bed, 2-foot 2-inch cut).	217	11414	A	1	15.10	36.67	42.51	5.72	3.82	......	......	......	......	12.7	......	......
				2	......	43.19	50.07	6.74	4.50	......	......	......	......	......	......	......
				3	......	46.31	53.69	......	4.83	......	......	......	......	......	......	......
Same (face, 200 feet southeast of shaft, 2-foot 6-inch bed, 2-foot 2-inch cut).	217	11415	A	1	15.48	35.93	40.54	8.05	4.89	......	......	......	......	13.3	......	......
				2	......	42.51	47.97	9.52	5.79	......	......	......	......	......	......	......
				3	......	46.98	53.02	......	6.40	......	......	......	......	......	......	......
Same (composite of samples 11413, 11414, and 11415).	217	11416	A	1	14.92	36.39	41.30	7.39	4.14	5.94	61.01	1.05	20.47	12.6	6,179	11,122
				2	......	42.77	48.54	8.69	4.87	5.03	71.71	1.23	8.47	......	7,263	13,073
				3	......	46.84	53.16	......	5.33	5.51	78.54	1.35	9.27	......	7,954	14,317
Marceline, ½ mile west of; sec. 20, T. 57 N., R. 18 W.; Landreth No. 1 mine, Tebo bed (face, 600 feet east of shaft, 2-foot 4-inch bed and cut).	218	11417	A	1	13.02	38.38	41.52	7.08	4.11	......	......	......	......	10.9	......	......
				2	......	44.13	47.73	8.14	4.73	......	......	......	......	......	......	......
				3	......	48.04	51.96	......	5.15	......	......	......	......	......	......	......
Same (face, 600 feet north of shaft, 2-foot 4-inch bed and cut).	218	11418	A	1	12.09	38.53	40.96	8.42	4.51	......	......	......	......	10.0	......	......
				2	......	43.83	46.59	9.58	5.13	......	......	......	......	......	......	......
				3	......	48.47	51.53	......	5.67	......	......	......	......	......	......	......
Same (face, 600 feet south of shaft, 2-foot 4-inch bed and cut).	218	11419	A	1	12.65	39.57	41.02	6.76	4.11	......	......	......	......	10.4	......	......
				2	......	45.30	46.96	7.74	4.71	......	......	......	......	......	......	......
				3	......	49.10	50.90	......	5.11	......	......	......	......	......	......	......
Same (composite of samples 11417, 11418, and 11419).	218	11420	A	1	12.51	39.29	40.76	7.44	4.27	5.85	63.02	1.08	18.34	10.4	6,380	11,484
				2	......	44.91	46.59	8.50	4.88	5.10	72.03	1.23	8.26	......	7,292	13,126
				3	......	49.08	50.92	......	5.38	5.57	78.72	1.34	9.04	......	7,969	14.344
PUTNAM COUNTY.																
Mendota, 1 mile southeast of; sec. 1, T. 66 N., R. 18 W.; Mendota No. 2 mine, Lexington bed (face, 2,500 feet southwest of shaft, 3-foot bed, 2-foot 10-inch cut).	218	11398	A	1	18.56	31.90	40.07	9.47	4.25	......	......	......	......	15.1	......	......
				2	......	39.17	49.20	11.63	5.22	......	......	......	......	......	......	......
				3	......	44.32	55.68	......	5.91	......	......	......	......	......	......	......
Same (face 3,200 feet south of shaft, 3-foot bed, 2-foot 10-inch cut).	218	11399	A	1	17.53	34.14	39.80	8.53	3.74	......	......	......	......	14.3	......	......
				2	......	41.40	48.26	10.34	4.54	......	......	......	......	......	......	......
				3	......	46.17	53.83	......	5.06	......	......	......	......	......	......	......
Same (face, 3,100 feet southeast of shaft, 3-foot bed, 2-foot 10-inch cut).	218	11400	A	1	19.11	31.49	37.92	11.48	4.33	......	......	......	......	16.1	......	......
				2	......	38.93	46.88	14.19	5.38	......	......	......	......	......	......	......
				3	......	45.37	54.63	......	6.27	......	......	......	......	......	......	......
Same (composite of samples 11398, 11399, and 11400).	218	11401	A	1	18.45	32.62	39.03	9.90	4.09	5.76	55.71	.91	23.63	15.2	5,578	10,040
				2	......	40.00	47.86	12.14	5.02	4.55	68.31	1.12	8.86	......	6,840	12,312
				3	......	45.53	54.47	......	5.71	5.18	77.75	1.27	10.09	......	7,785	14,013
Unionville, 2½ miles northeast of; NW. ¼ sec. 30, T. 66 N., R. 19 W.; Anderson mine, Lexington bed (in mine, about 175 feet southwest of shaft; 2-foot 8½-inch bed, 2-foot 6-inch cut).	219	*14880	B	1	16.51	34.39	37.33	11.77	3.39	......	......	......	......	12.8	5,600	10,080
				2	......	41.19	44.71	14.10	4.06	......	......	......	......	......	6,707	12,073
				3	......	47.95	52.05	......	4.73	......	......	......	......	......	7,808	14,054
Same (about 150 feet east of shaft: 2-foot 10-inch bed, 2-foot 6½-inch cut).	219	*14881	B	1	16.52	34.76	37.39	11.33	2.88	......	......	......	......	12.8	5,563	10,013
				2	......	41.64	44.79	13.57	3.45	......	......	......	......	......	6,664	11,995
				3	......	48.18	51.82	......	3.99	......	......	......	......	......	7,710	13,878

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
MISSOURI—Continued.																
RANDOLPH COUNTY.																
Huntsville, southern part of; sec. 36, T. 54 N., R. 15 W.; Carson No. 1 mine, Bevier bed (face, 250 feet southeast of shaft, 4-foot bed and cut).	219	11452	A	1	13.35	35.06	41.32	10.27	5.56					11.5		
				2		40.46	47.69	11.85	6.42							
				3		45.90	54.10		7.28							
Same (face, 300 feet north of shaft, 4-foot bed and cut).	219	11453	A	1	13.36	34.79	42.02	9.83	5.20					11.5		
				2		40.15	48.50	11.35	6.00							
				3		45.29	54.71		6.77							
Same (face, 200 feet southwest of shaft, 4-foot bed and cut).	219	11454	A	1	13.31	34.71	41.67	10.31	5.12					11.6		
				2		40.04	48.07	11.89	5.91							
				3		45.44	54.56		6.71							
Same (composite of samples 11452, 11453, and 11454).	219	11455	A	1	13.23	34.99	41.53	10.25	5.19	5.58	60.25	0.92	17.81	11.5	6,101	10,982
				2		40.33	47.86	11.81	5.98	4.74	69.44	1.06	6.97		7,031	12,656
				3		45.73	54.27		6.78	5.37	78.74	1.20	7.91		7,972	14,350
¾ mile south of: sec. 36, T. 54 N., R. 15 W.; Northern No. 2 mine, Bevier bed (face, 4,000 feet south of shaft, 4-foot bed and cut).	219	11448	A	1	12.46	36.94	42.80	7.80	2.99					10.6		
				24		42.20	48.89	8.91	3.42							
				3		46.33	53.67		3.75							
Same (face, 3,800 feet northeast of shaft, 4-foot bed and cut).	219	11449	A	1	13.03	35.75	41.82	9.40	4.34					11.2		
				2		41.11	48.08	10.81	4.99							
				3		46.09	53.91		5.59							
Same (face, 3,500 feet southeast of shaft, 4-foot bed and cut).	219	11450	A	1	10.53	36.50	43.90	9.07	4.46					8.4		
				2		40.80	49.06	10.14	4.98							
				3		45.40	54.60		5.54							
Same (composite of samples 11448, 11449, and 11450).	220	11451	A	1	12.12	36.32	42.88	8.68	3.92	5.58	63.32	1.02	17.48	10.1	6,363	11,453
				2		41.33	48.79	9.88	4.46	4.81	72.05	1.16	7.64		7,240	13,032
				3		45.86	54.14		4.95	5.34	79.95	1.29	8.47		8,034	14,461
Renick, ½ mile west of; sec. 31, T. 53 N., R. 13 W.; Orris No. 1 mine; Mulky bed (face, 300 feet southwest of shaft, 18-inch bed and cut).	220	11497	A	1	9.82	38.15	43.08	8.95	4.68					7.9		
				2		42.30	47.78	9.92	5.20							
				3		46.96	53.04		5.77							
Same (face, 300 feet northwest of shaft, 18-inch bed and cut).	220	11498	A	1	7.38	41.09	43.68	7.85	4.04					5.1		
				2		44.36	47.16	8.48	4.36							
				3		48.47	51.53		4.76							

Same (face, 300 feet west of shaft, 18-inch bed and cut).	220	11499	A	1	8.83	39.76	42.95	8.46	5.35	....	....	....	....	6.7	....	....
				2	....	43.61	47.11	9.28	5.87	....	....	....	....	....	....	....
				3	....	48.07	51.93	....	6.47	....	....	....	....	....	....	....
Same (composite of samples 11497, 11498, and 11499, 18-inch bed and cut).	220	11500	A	1	8.71	39.87	42.88	8.54	4.64	5.61	66.08	.94	14.19	6.6	6,706	12,071
				2	....	43.67	46.98	9.35	5.08	5.08	72.38	1.03	7.08	....	7,346	13,223
				3	....	48.17	51.83	....	5.60	5.60	79.84	1.14	7.82	....	8,103	14,585
RAY COUNTY.																
Vibbard, ¼ mile south of; sec. 27, T. 53 N., R. 29 W.; Vibbard No. 1 mine, Lexington bed (face, 250 feet south of shaft, 2-foot 4-inch bed, 2-foot cut).	220	11365	A	1	11.89	38.00	42.68	7.43	2.95	....	....	....	....	7.2	....	....
				2	....	43.13	48.44	8.43	3.35	....	....	....	....	....	....	....
				3	....	47.10	52.90	....	3.66	....	....	....	....	....	....	....
Same (face, 250 feet east of shaft, 2-foot 4-inch bed, 2-foot cut).	220	11366	A	1	13.58	36.55	43.77	6.10	2.23	....	....	....	....	8.4	....	....
				2	....	42.29	50.65	7.06	2.58	....	....	....	....	....	....	....
				3	....	45.50	54.50	....	2.78	....	....	....	....	....	....	....
Same (face, 200 feet west of shaft, 2-foot 4-inch bed, 2-foot cut).	220	11367	A	1	13.83	36.47	42.60	7.10	3.00	....	....	....	....	9.2	....	....
				2	....	42.32	49.44	8.24	3.48	....	....	....	....	....	....	....
				3	....	46.12	53.88	....	3.79	....	....	....	....	....	....	....
Same (composite of samples 11365, 11366, and 11367).	220	11368	A	1	13.08	36.94	43.15	6.83	2.79	5.73	64.22	.99	19.44	8.3	6,417	11,551
				2	....	42.50	49.64	7.86	3.21	4.92	73.89	1.14	8.98	....	7,383	13,289
				3	....	46.13	53.87	....	3.48	5.34	80.19	1.24	9.75	....	8,013	14,423
VERNON COUNTY.																
Moundville, northwest corner of; sec. 5, T. 34 N., R. 32 W.; Brown No. 1 mine (face, 40 feet northwest of shaft, 2-foot 2-inch cut).	221	11201	A	1	5.68	33.67	50.05	10.60	5.00	....	....	....	....	4.2	....	....
				2	....	35.70	53.06	11.24	5.30	....	....	....	....	....	....	....
				3	....	40.22	59.78	....	5.97	....	....	....	....	....	....	....
Same (face, 100 feet northeast of shaft, 2-foot 2-inch cut).	221	11202	A	1	5.98	33.10	52.48	8.44	3.86	....	....	....	....	4.6	....	....
				2	....	35.21	55.81	8.98	4.11	....	....	....	....	....	....	....
				3	....	38.69	61.31	....	4.52	....	....	....	....	....	....	....
Same (face, 125 feet north of shaft, 2-foot 2-inch cut).	221	11203	A	1	7.93	30.05	50.99	11.03	5.89	....	....	....	....	6.6	....	....
				2	....	32.64	55.38	11.98	6.40	....	....	....	....	....	....	....
				3	....	37.08	62.92	....	7.27	....	....	....	....	....	....	....
Same (composite of samples 11201, 11202, and 11203).	221	11204	A	1	6.50	32.61	50.83	10.06	4.95	5.21	67.97	1.09	10.72	5.1	6,921	12,458
				2	....	34.88	54.36	10.76	5.29	4.80	72.69	1.17	5.29	....	7,402	13,324
				3	....	39.09	60.91	....	5.93	5.38	81.46	1.31	5.92	....	8,295	14,931
Panama, 2 miles south of; sec. 4, T. 37 N., R. 31 W.; Jones No. 1 mine, Rich Hill bed (face, 450 feet east of shaft, 5-foot cut).	221	11205	A	1	6.22	35.36	42.89	15.53	5.45	....	....	....	....	5.0	....	....
				2	....	37.70	45.74	16.56	5.81	....	....	....	....	....	....	....
				3	....	45.18	54.82	....	6.96	....	....	....	....	....	....	....
Same (face, 1,000 feet southeast of shaft, 5-foot cut)	221	11206	A	1	6.49	34.40	43.64	15.47	5.88	....	....	....	....	4.7	....	....
				2	....	36.79	46.67	16.54	6.29	....	....	....	....	....	....	....
				3	....	44.08	55.92	....	7.54	....	....	....	....	....	....	....
Same (face, 100 feet east of shaft, 5-foot cut)......	221	11207	A	1	5.21	36.67	45.51	12.61	5.92	....	....	....	....	3.5	....	....
				2	....	38.69	48.01	13.30	6.25	....	....	....	....	....	....	....
				3	....	44.63	55.37	....	7.21	....	....	....	....	....	....	....
Same (composite of samples 11205, 11206, and 11207).	221	11208	A	1	6.02	35.94	43.37	14.67	5.84	5.27	63.55	1.03	9.64	4.4	6,579	11,842
				2	....	38.24	46.15	15.61	6.21	4.89	67.62	1.10	4.57	....	7,001	12,602
				3	....	45.31	54.69	....	7.36	5.79	80.13	1.30	5.42	....	8,296	14,933

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
MONTANA.																
BLAINE COUNTY.																
Cleveland, 4 miles northeast of, about 25 miles southeast of Chinook; SW. ¼ sec. 35, T. 30 N., R. 20 E; Cook mine (face of entry, 500 feet from mine mouth; 3 foot 6¼ inch bed, 3-foot 1-inch cut.)	222	*14782	B	1	18.77	31.48	40.40	9.35	0.73					7.1	5,075	9,135
				2		38.76	49.73	11.51	.90						6,248	11,246
				3		43.80	56.20		1.02						7,061	12,710
CARBON COUNTY.																
Bear Creek, 1½ miles west of; sec. 6, T. 8 S., R. 21 E; No. 2 mine, No. 2 bed (pillar between rooms 9 and 10, off north entry 2; 6-foot 2½-inch bed and cut).	222	*15151	A	1	9.94	35.06	43.82	11.19	1.75					3.1	5,897	10,615
				2		38.92	48.65	12.43	1.94						6,548	11,786
				3		44.44	55.56		2.22						7,477	13,459
Same (position, bed, and cut same as sample 15151).	222	*15145	A	1	10.07	34.78	44.10	11.05	1.83					3.2	5,935	10,683
				2		38.68	49.03	12.29	2.03						6,600	11,880
				3		44.10	55.90		2.31						7,525	13,545
Same (face of room 10, west entry 1; 125 feet in from entry; 6-foot 4-inch bed and cut).	222	*15146	A	1	10.39	34.12	47.56	7.93	1.31					3.4	6,096	10,973
				2		38.07	53.08	8.85	1.46						6,803	12,245
				3		41.77	58.23		1.60						7,464	13,435
Same (position, bed, and cut same as sample 15146).	222	*15152	A	1	10.40	34.66	46.68	8.26	1.28					3.2	6,095	10,971
				2		38.68	52.10	9.22	1.43						6,803	12,245
				3		42.61	57.39		1.58						7,494	13,489
Same (face of room 9 off east entry 9; 45 feet in from entry; 5-foot 6½-inch bed and cut).	222	*15147	A	1	10.66	35.18	44.79	9.37	1.66					3.6	5,968	10,724
				2		39.38	50.13	10.49	1.86						6,669	12,004
				3		44.00	56.00		2.08						7,451	13,412
Same (position, bed, and cut same as sample 15147).	222	*15153	A	1	10.67	34.75	45.13	9.45	1.65					3.7	5,950	10,710
				2		38.90	50.52	10.58	1.85						6,660	11,988
				3		43.50	56.50		2.07						7,448	13,406
Same (face of last crosscut, just started, in room 22, off east entry 4; 6-foot 3½-inch bed and cut).	222	*15148	A	1	11.07	34.11	46.67	8.15	1.47					3.9	6,028	10,850
				2		38.36	52.48	9.16	1.65						6,778	12,200
				3		42.23	57.77		1.82						7,461	13,430
Same (position, bed, and cut same as sample 15148).	222	*15154	A	1	11.11	33.65	46.89	8.35	1.44					3.9	6,010	10,818
				2		37.86	52.75	9.39	1.62						6,761	12,170
				3		41.78	58.22		1.79						7,461	13,430

Same (face of room 11, off rock tunnel entry, 35 feet in from entry, 5-foot 9-inch bed and cut).	222	*15149	A	1	10.80	35.06	44.02	10.12	1.82	....	....	....	....	3.8	5,885	10,593
				2	....	39.31	49.34	11.35	2.04	....	....	....	....	....	6,598	11,876
				3	....	44.34	55.66	....	2.30	....	....	....	....	....	7,443	13,397
Same (position, bed, and cut same as sample 15149).	222	*15155	A	1	10.75	35.19	43.60	10.46	1.80	....	....	....	....	3.9	5,861	10,550
				2	....	39.43	48.85	11.72	2.02	....	....	....	....	....	6,567	11,821
				3	....	44.67	55.33	....	2.29	....	....	....	....	....	7,439	13,390
Same (composite of samples 15146, 15147, 15148, and 15149).	223	*15150	A	1	10.66	35.29	45.14	8.91	1.58	5.55	61.22	1.58	21.16	3.7	5,986	10,775
				2	....	39.50	50.53	9.97	1.77	4.89	68.52	1.77	13.08	....	6,700	12,060
				3	....	43.87	56.13	....	1.97	5.43	76.11	1.97	14.52	....	7,442	13,396
Same (composite of samples 15152, 15153, 15154, and 15155).	223	*15156	A	1	10.65	34.10	46.11	9.14	1.53	5.50	60.87	1.58	21.38	3.7	5,997	10,795
				2	....	38.16	51.61	10.23	1.71	4.83	68.13	1.77	13.33	....	6,712	12,082
				3	....	42.51	57.49	....	1.90	5.38	75.90	1.97	14.85	....	7,477	13,459
Secs. 5 and 6, T. 8 S., R. 21 E; North Side mine, No. 3 bed (last pillar on second west main entry, 500 feet from drift mouth, 5-foot 6-inch bed and cut).	224	*15143	A	1	10.23	34.96	45.95	8.86	1.55	....	....	....	....	3.5	6,120	11,016
				2	....	38.95	51.18	9.87	1.73	....	....	....	....	....	6,818	12,272
				3	....	43.22	56.78	....	1.92	....	....	....	....	....	7,565	13,617
Same (position, bed, and cut same as sample 15143).	224	*15144	A	1	10.12	34.54	46.63	8.71	1.67	....	....	....	....	3.2	6,130	11,034
				2	....	38.43	51.88	9.69	1.86	....	....	....	....	....	6,820	12,276
				3	....	42.55	57.45	....	2.06	....	....	....	....	....	7,552	13,594
1 mile west of; sec. 6, T. 8 S., R. 21 E.; South Side mine, No. 3 bed (face of room 2 off north entry 1, 50 feet in from entry, 7-foot 11-inch bed, 6-foot 11-inch cut).	223	*15127	A	1	10.30	34.31	44.03	11.36	2.19	....	....	....	....	2.9	5,859	10,546
				2	....	38.25	49.09	12.66	2.44	....	....	....	....	....	6,532	11,758
				3	....	43.80	56.20	....	2.79	....	....	....	....	....	7,479	13,462
Same (position, bed, and cut same as sample 15127).	223	*15133	A	1	10.22	33.98	44.12	11.68	2.09	....	....	....	....	2.7	5,854	10,537
				2	....	37.85	49.14	13.01	2.33	....	....	....	....	....	6,520	11,736
				3	....	43.51	56.49	....	2.68	....	....	....	....	....	7,495	13,491
Same (in crosscut from main entry to back entry, 350 feet from mouth of main entry and 75 feet from face of back entry, 7-foot 8-inch bed, 7-foot 4-inch cut).	223	*15128	A	1	9.99	34.65	44.45	10.91	2.53	....	....	....	....	2.9	5,898	10,616
				2	....	38.50	49.38	12.12	2.81	....	....	....	....	....	6,553	11,795
				3	....	43.81	56.19	....	3.20	....	....	....	....	....	7,457	13,423
Same (position, bed, and cut same as sample 15128).	223	*15132	A	1	10.10	34.65	43.96	11.29	2.41	....	....	....	....	2.9	5,870	10,566
				2	....	38.54	48.90	12.56	2.68	....	....	....	....	....	6,529	11,752
				3	....	44.07	55.93	....	3.06	....	....	....	....	....	7,467	13,441
Same (face of south back entry 1, 150 feet from main slope, 7-foot 2-inch bed, 6-foot 7-inch cut).	223	*15129	A	1	9.80	33.62	45.02	11.56	1.95	....	....	....	....	3.2	5,910	10,638
				2	....	37.27	49.91	12.82	2.16	....	....	....	....	....	6,552	11,794
				3	....	42.75	57.25	....	2.48	....	....	....	....	....	7,516	13,529
Same (position, bed, and cut same as sample 15129).	223	*15131	A	1	9.60	33.47	45.37	11.56	2.00	....	....	....	....	3.1	5,900	10,620
				2	....	37.02	50.19	12.79	2.21	....	....	....	....	....	6,527	11,749
				3	....	42.45	57.55	....	2.53	....	....	....	....	....	7,485	13,473
Same (composite of samples 15127, 15128, and 15129).	224	*15130	A	1	9.95	33.93	44.81	11.31	2.26	5.28	59.13	1.41	20.61	3.0	5,885	10,593
				2	....	37.68	49.76	12.56	2.51	4.63	65.66	1.57	13.07	....	6,535	11,763
				3	....	43.09	56.91	....	2.87	5.29	75.09	1.80	14.95	....	7,473	13,451
Same (composite of samples 15131, 15132, and 15133).	224	*15134	A	1	9.87	34.00	44.61	11.52	2.25	5.32	59.79	1.47	19.65	2.9	5,882	10,588
				2	....	37.72	49.50	12.78	2.50	4.68	66.34	1.63	12.07	....	6,526	11,74
				3	....	43.25	56.75	....	2.87	5.37	76.06	1.87	13.83	....	7,482	13,468

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
MONTANA—Continued.																
CHOUTEAU COUNTY.																
Big Sandy, 6 miles northeast of; NW. ¼ SW. ¼ sec. 18 T. 28 N., R. 14 E., Mackton mine; Mackton bed (face of north entry on second level, 335 feet below mouth of slope and 140 feet from mouth of entry, 7-foot 5-inch bed, 5-foot 6-inch cut).	225	*14613	B	1	13.03	36.29	40.06	10.62	0.53	......	......	......	......	1.8	5,342	9,616
				2	......	41.73	46.06	12.21	.61	......	......	......	......	......	6,142	11,056
				3	......	47.53	52.47	......	.69	......	......	......	......	......	6,996	12,593
Same (face of upper south entry, 250 feet from mouth of entry and 150 feet below mouth of slope; 7-foot 6-inch bed, 6-foot 1-inch cut).	225	*14615	B	1	12.36	36.93	35.78	14.93	.70	......	......	......	......	1.9	5,052	9,094
				2	......	42.14	40.82	17.04	.80	......	......	......	......	......	5,764	10,375
				3	......	50.80	49.20	......	.96	......	......	......	......	......	6,948	12,506
CUSTER COUNTY.																
Terry, 4 miles west of; sec. 24, T. 12 N., R. 50 E.; Cameron mine (8-foot 1-inch bed, 3-foot 5-inch cut).	225	10677	B	1	28.16	......	......	15.91	.27	......	......	......	......	19.9	3,503	6,305
				2	......	......	......	22.15	.38	......	......	......	......	......	4,876	8,777
				3	......	......	......	......	.49	......	......	......	......	......	6,263	11,273
Westmore, 17 miles south of; sec. 34, T. 6 N., R. 57 E.; prospect.	226	*10910	B	1	38.67	27.02	25.10	9.21	.30	......	......	......	......	26.2	3,345	6,021
				2	......	44.06	40.92	15.02	.49	......	......	......	......	......	5,454	9,817
				3	......	51.84	48.16	......	.58	......	......	......	......	......	6,418	11,552
DAWSON COUNTY.																
Glendive, 15 miles northeast of; sec. 31, T. 18 N., R. 57 E.; prospect (right wall, 25 feet from outcrop).	226	*10914	B	1	31.52	28.61	33.54	6.33	.65	......	......	......	......	17.2	3,822	6,880
				2	......	41.78	48.98	9.24	.95	......	......	......	......	......	5,581	10,046
				3	......	46.03	53.97	......	1.05	......	......	......	......	......	6,149	11,068
6¼ miles north of; sec. 27, T. 17 N., R. 55 E.; Snyder mine, middle bed of the Fort Union (face, 80 feet from mine mouth).	226	*11045	B	1	32.13	25.55	34.23	8.09	1.36	......	......	......	......	23.4	3,948	7,106
				2	......	37.65	50.43	11.92	2.00	......	......	......	......	......	5,817	10,471
				3	......	42.74	57.26	......	2.27	......	......	......	......	......	6,604	11,887
FERGUS COUNTY.																
Hilger, 13 miles north of; sec. 8, T. 19 N., R. 19 E., Stone mine (face of entry, 140 feet from mine mouth, 6-foot bed, 4-foot 4-inch cut).	227	*14495	B	1	23.11	33.47	30.61	12.81	1.08	......	......	......	......	11.1	4,305	7,749
				2	......	43.53	39.81	16.66	1.40	......	......	......	......	......	5,599	10,078
				3	......	52.23	47.77	......	1.68	......	......	......	......	......	6,718	12,092

FLATHEAD COUNTY.																
Flathead River, North Fork of; sec. 33, T. 34 N., R. 20 W., outcrop (surface exposure, 6-foot 9-inch bed, 3-foot 6-inch cut).	227	*12786	B	1	22.16	32.52	36.44	8.88	2.27	......	......	......	......	10.0	4,890	8,801
				2	......	41.78	46.81	11.41	2.92	......	......	......	......	......	6,282	11,307
				3	......	47.16	52.84	......	3.30	......	......	......	......	......	7,091	12,763
MISSOULA COUNTY.																
Missoula, 2 miles north of; sec. 4, T. 13 N., R. 19 W., Hell Gate mine (run of mine, from bunker at mouth of mine, represents coal from east entry; 6-foot bed).	228	*13541	B	1	24.70	29.33	26.11	19.86	.85	5.56	39.04	0.74	33.95	16.3	3,737	6,727
				2	......	38.95	34.68	26.37	1.13	3.74	51.85	0.98	15.93	......	4,963	8,933
				3	......	52.90	47.10	......	1.53	5.08	70.42	1.33	21.64	......	6,740	12,132
Same (in east entry off slope entry, 600 feet north and 300 feet east of mine mouth, 6-foot 10-inch bed).	228	*13542	B	1	25.21	29.19	26.01	19.59	.76	......	......	......	......	16.7	......	......
				2	......	39.03	34.78	26.19	1.02	......	......	......	......	......	......	......
				3	......	52.88	47.12	......	1.38	......	......	......	......	......	......	......
MUSSELSHELL COUNTY.																
Painted Rock, 1 mile northwest of; sec. 14, T. 5 N., R. 22 E.; Sholz mine (face of north main entry, 110 feet from mouth of entry, 2-foot 11-inch cut).	228	15114	B	1	11.59	31.82	40.35	16.24	1.00	......	......	......	......	4.5	5,563	10,013
				2	......	35.99	45.64	18.37	1.13	......	......	......	......	......	6,292	11,326
				3	......	44.09	55.91	......	1.38	......	......	......	......	......	7,708	13,874
ROSEBUD COUNTY.																
Bighorn, 6½ miles east of; sec. 2, T. 4 N., R. 35 E., prospect (10 feet from outcrop, 3-foot 2½-inch bed).	228	*14755	B	1	19.79	30.67	35.19	14.35	1.50	......	......	......	......	8.5	4,766	8,579
				2	......	38.24	43.87	17.89	1.87	......	......	......	......	......	5,942	10,696
				3	......	46.57	53.43	......	2.28	......	......	......	......	......	7,237	13,027
TETON COUNTY.																
Browning, 22 miles northwest of; SE. ¼ NE. ¼ sec. 35, T. 36 N., R. 12 W., J. M. Stone prospect (face of entry, 50 feet from mouth of entry).	229	12602	B	1	8.00	35.37	44.18	12.45	1.00	5.17	62.92	1.46	17.00	2.3	6,137	11,047
				2	......	38.45	48.02	13.53	1.09	4.65	68.39	1.59	10.75	......	6,671	12,008
				3	......	44.47	55.53	......	1.26	5.38	79.09	1.84	12.43	......	7,715	13,887
Cut Bank, 5 miles northwest of; NE. ¼ sec. 29, T. 34 N., R. 6 W.; Allison prospect (in entry, 22-inch bed).	229	12494	B	1	7.82	30.21	34.24	27.73	1.78	......	......	......	......	2.9	4,837	8,707
				2	......	32.77	37.15	30.08	1.93	......	......	......	......	......	5,247	9,445
				3	......	46.87	53.13	......	2.76	......	......	......	......	......	7,504	13,507
4 miles southwest of; NE. ¼ SW. ¼ sec 26, T. 33 N., R. 6 W.; prospect (in fresh open cut, 11-inch cut).	229	*14109	B	1	16.57	29.21	36.25	17.97	.59	......	......	......	......	6.2	......	......
				2	......	35.01	43.45	21.54	.71	......	......	......	......	......	......	......
				3	......	44.62	55.38	......	.90	......	......	......	......	......	......	......
Valier, 8 miles northwest of, on Birch Creek; SW. ¼ NW. ¼ sec. 32, T. 31 N., R. 5 W.; Blair mine (face of new entry 150 feet in, 2-foot 3-inch cut).	229	12427	B	1	6.56	40.36	39.19	13.89	3.08	5.16	60.71	1.13	16.03	1.3	6,070	10,926
				2	......	43.19	41.94	14.87	3.30	4.74	64.97	1.21	10.91	......	6,496	11,693
				3	......	50.74	49.26	......	3.88	5.57	76.32	1.42	12.81	......	7,631	13,736
VALLEY COUNTY.																
Antelope, 3 miles west of; sec. 21, T. 34 N., R. 55 E.; Richardson mine, "Richardson" bed (in new entry, 200 feet north of mouth of entry, 8-foot 3-inch cut).	230	*14614	B	1	29.14	29.65	33.82	7.39	.31	......	......	......	......	5.4	4,167	7,501
				2	......	41.84	47.73	10.43	.44	......	......	......	......	......	5,880	10,584
				3	......	46.71	53.29	......	.49	......	......	......	......	......	6,564	11,815
Bainville, 8 miles northeast of; sec. 10, T. 28 N., R. 59 E.; Red Bank mine, Red Bank bed (full section taken at face).	230	*10898	B	1	42.81	25.72	26.83	4.64	.24	7.21	36.21	.62	51.08	35.3	3,392	6,105
				2	......	44.97	46.92	8.11	.42	4.28	63.31	1.08	22.80	......	5,931	10,675
				3	......	48.94	51.06	......	.46	4.66	68.90	1.18	24.80	......	6,455	11,618

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
MONTANA—Continued.																
VALLEY COUNTY—continued.																
Culbertson, 3 miles north of; sec. 8, T. 28 N., R. 56 E.; Bruegger mine, E bed (75 feet north of mine mouth).	231	*10724	B	1	32.62	27.43	30.85	9.10	1.28	6.46	40.35	0.70	42.11	23.6	3,729	6,712
				2	....	40.71	45.79	13.50	1.90	4.21	59.88	1.04	19.47	....	5,534	9,961
				3	....	47.06	52.94	....	2.20	4.86	69.23	1.20	22.51	....	6,398	11,516
3¾ miles southeast of; sec. 3, T. 27 N., R. 56 E.; Butterfield mine, DD bed (150 feet from mine mouth, 4½-foot cut).	231	*10727	B	1	37.51	26.82	29.61	6.06	.32	6.75	39.88	.65	46.34	26.0	3,655	6,580
				2	....	42.92	47.38	9.70	.51	4.13	63.82	1.04	20.80	....	5,849	10,529
				3	....	47.53	52.47	....	.56	4.57	70.67	1.15	23.05	....	6,477	11,660
3 miles southeast of; sec. 34, T. 28 N., R. 56 E.; Dempsey mine, E bed (face, about 60 feet northeast of mine mouth).	231	*10725	B	1	38.88	27.21	27.68	6.23	.75	6.89	36.59	.74	48.80	29.2	3,341	6,014
				2	....	44.52	45.29	10.19	1.23	4.20	59.86	1.21	23.31	....	5,466	9,839
				3	....	49.57	50.43	....	1.37	4.68	66.65	1.35	25.95	....	6,086	10,955
3 miles southeast of; sec. 34, T. 28 N., R. 56 E., ½ mile from sample 10725; prospect, F bed (face, 50 feet from opening).	232	*10726	B	1	35.33	31.80	25.14	7.73	1.13	6.28	34.98	.83	49.05	26.3	3,002	5,404
				2	....	49.17	38.88	11.95	1.75	3.63	54.09	1.28	27.30	....	4,642	8,356
				3	....	55.84	44.16	....	1.99	4.12	61.43	1.45	31.01	....	5,272	9,490
Froid, 5½ miles southwest of; sec. 15, T. 29 N., R. 55 E.; Astrope mine (in entry, 115 feet north of mouth of entry).	232	*11005	B	1	40.74	25.20	27.83	6.23	.72	7.11	36.57	.68	48.69	35.0	3,415	6,147
				2	....	42.53	46.96	10.51	1.22	4.35	61.71	1.15	21.06	....	5,763	10,375
				3	....	47.52	52.48	....	1.36	4.86	68.95	1.29	23.54	....	6,440	11,592
3½ miles south of; sec. 11, T. 29 N., R. 55 E.; prospect, F bed (from a well which penetrated bed).	232	*11004	B	1	37.73	25.83	30.93	5.51	.75	7.01	39.66	.71	46.36	31.5	3,722	6,700
				2	....	41.48	49.67	8.85	1.20	4.53	63.69	1.14	20.59	....	5,977	10,759
				3	....	45.51	54.49	....	1.32	4.97	69.87	1.25	22.59	....	6,558	11,804
Medicine Lake, 15 miles east of; sec. 4, T. 31 N., R. 59 E.; Belgon mine (face of pit).	232	*10899	B	1	41.29	25.66	28.22	4.83	.36	7.12	37.18	.65	49.86	33.9	3,478	6,260
				2	....	43.71	48.06	8.23	.61	4.31	63.33	1.11	22.41	....	5,924	10,663
				3	....	47.63	52.37	....	.66	4.70	60.01	1.21	24.42	....	6,455	11,619
22 miles northeast of; sec. 8, T. 34 N., R. 58 E.; Coal Ridge mine, Coal Ridge bed (face of entry, about 400 feet from mine mouth).	233	*11002	B	1	40.41	24.50	27.58	7.51	.39	6.94	35.15	.57	49.44	35.2	3,239	5,830
				2	....	41.11	46.29	12.60	.65	4.11	58.99	.96	22.69	....	5,435	9,783
				3	....	47.04	52.96	....	.74	4.70	67.50	1.10	25.96	....	6,219	11,194
6 miles northeast of; sec. 30, T. 33 N., R. 56 E.; Jones mine, Jones bed (in entry, 250 feet south of entry mouth).	233	*11006	B	1	41.63	26.66	26.14	5.57	.40	6.81	33.48	.66	53.08	35.6	2,982	5,278
				2	....	45.67	44.79	9.54	.69	3.73	57.36	1.13	27.55	....	5,023	9,041
				3	....	50.49	49.51	....	.76	4.12	63.41	1.25	30.46	....	5,553	9,995
2½ miles southeast of; sec. 6, T. 31 N., R. 56 E.; Ted Young mine, Young bed (in mine, 300 feet southeast of mine mouth).	233	*11003	B	1	39.31	24.15	30.80	5.74	.53	6.92	37.80	.65	48.36	33.2	3,488	6,278
				2	....	39.79	50.75	9.46	.87	4.20	62.28	1.07	22.12	....	5,747	10,345
				3	....	43.95	56.05	....	.96	4.64	68.79	1.18	24.43	....	6,348	11,426

Mondak, 7 miles northwest of, 1½ miles from the Great Northern Railway; sec. 18, T. 27 N., R. 59 E.; open pit.	234	*10900	B	1	41.63	27.11	27.18	4.08	.37	6.83	36.04	.77	51.91	33.3	3,185	5,733
				2	......	46.44	46.57	6.99	.63	3.77	61.74	1.32	25.55	......	5,457	9,823
				3	......	49.93	50.07	......	.68	4.05	66.38	1.42	27.47	......	5,867	10,562
Plentywood, 2½ miles northeast of; sec. 10, T. 35 N., R. 55 E.; Pierce mine, "Richardson" bed (in mine, about 250 feet northwest of mine mouth, 8-foot bed, 6-foot 6-inch cut).	234	*14670	B	1	34.29	29.56	28.06	8.09	.66	......	......	......	......	5.9	3,756	6,761
				2	......	44.98	42.71	12.31	1.00	......	......	......	......	......	5,716	10,289
				3	......	51.30	48.70	......	1.14	......	......	......	......	......	6,519	11,734
NEVADA.																
ESMERALDA COUNTY.																
Coaldale, 3½ miles southeast of; sec. 33, T. 2 N., R. 37 E.; Darms mine, C bed (in drift, off slope, 300 feet from mouth of slope and 20 feet from slope, 7-foot bed and cut).	234	13978	B	1	2.08	33.67	33.74	30.51	7.18	......	......	......	......	.6	5,329	9,592
				2	......	34.38	34.46	31.16	7.33	......	......	......	......	......	5,442	9,796
				3	......	49.94	50.06	......	10.65	......	......	......	......	......	7,905	14,229
about 3½ miles southeast of; sec. 29, T. 2 N., R. 37 E.; Nevada mine, C bed (150 feet from mouth of entry, 9-foot bed and cut.)	235	13979	B	1	1.89	26.74	27.42	43.95	.60	......	......	......	......	.7	4,499	8,098
				2	......	27.26	27.94	44.80	.61	......	......	......	......	......	4,586	8,255
				3	......	49.38	50.62	......	1.11	......	......	......	......	......	8,308	14,954
Same (about 100 feet from mouth of entry, 8-foot bed and cut).	235	13980	B	1	1.65	31.31	35.48	31.56	7.42	......	......	......	......	.2	5,331	9,596
				2	......	31.84	36.07	32.09	7.54	......	......	......	......	......	5,421	9,758
				3	......	46.88	53.12	......	11.10	......	......	......	......	......	7,982	14,368
Same (sample cut from block of best coal, 12-inch cut).	235	14409	B	1	1.61	39.18	43.79	15.42	6.64	......	......	......	......	.1	6,766	12,179
				2	......	39.82	44.51	15.67	6.75	......	......	......	......	......	6,877	12,379
				3	......	47.22	52.78	......	8.00	......	......	......	......	......	8,155	14,679
NEW MEXICO.																
BERNALILLO COUNTY.																
Albuquerque, about 25 miles east of; sec. 6, T. 10 N., R. 6 E.; Holmes mine (at face in entry, 300 feet from entry mouth, 2-foot 3-inch cut).	235	12650	B	1	1.61	31.11	36.14	31.14	3.24	......	......	......	......	.5	5,581	10,046
				2	......	31.62	36.73	31.65	3.29	......	......	......	......	......	5,673	10,211
				3	......	46.26	53.74	......	4.81	......	......	......	......	......	8,300	14,940
COLFAX COUNTY.																
Dawson; secs. 1, 2, 11, and 12, T. 29 N., and secs. 35 and 36, T. 28 N., R. 20 E.; Dawson No. 2 mine, Raton bed (face of north entry 5; 6,700 feet northeast of "high line" entrance).	236	12233	A	1	2.95	35.08	49.15	12.82	.92	......	......	......	......	1.4	......	......
				2	......	36.15	50.64	13.21	.95	......	......	......	......	......	......	......
				3	......	41.65	58.35	......	1.09	......	......	......	......	......	......	......
Same (face of east entry 13; 6,500 feet from "high line" entrance).	236	12234	A	1	3.75	36.47	48.12	11.66	.59	......	......	......	......	2.0	......	......
				2	......	37.89	50.00	12.11	.61	......	......	......	......	......	......	......
				3	......	43.11	56.89	......	.69	......	......	......	......	......	......	......
Same (composite of samples 12233 and 12234) ...	236	12235	A	1	3.32	35.68	48.66	12.34	.71	5.31	70.35	1.19	10.10	1.7	7,087	12,757
				2	......	36.90	50.34	12.76	.73	5.11	72.76	1.23	7.41	......	7,330	13,194
				3	......	42.30	57.70	......	.84	5.86	83.40	1.41	8.49	......	8,402	15,124
Gardiner, ½ mile southeast of Blossburg; Gardiner No. 1 mine Raton bed (face of room 6, west entry 1, off main entry, 400 feet from outcrop; 6-foot bed, 5-foot 5-inch cut).	236	14795	B	1	2.34	36.70	45.73	15.23	.64	5.13	67.91	1.30	9.79	.9	6,809	12,256
				2	......	37.58	46.82	15.60	.66	4.99	69.54	1.33	7.88	......	6,972	12,550
				3	......	44.52	55.48	......	.78	5.91	82.39	1.58	9.34	......	8,260	14,868

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
NEW MEXICO—Continued.																
COLFAX COUNTY—continued.																
Koehler; T. 29 N., R. 22 E.; Koehler No. 1 mine, Raton bed (face of room 20, off east entry 7; 4,500 feet southeast of mouth of main entry, 9-foot bed, 6-foot cut).	237	12335	A	1	4.96	36.32	48.98	9.74	0.62	......	......	......	......	3.4	......	......
				2	......	38.22	51.53	10.25	.65	......	......	......	......	......	......	......
				3	......	42.58	57.42	......	.72	......	......	......	......	......	......	......
Same (face of west entry 8; 4,300 feet southeast of mouth of main entry, 8-foot 2-inch bed, 6-foot 2-inch cut).	237	12336	A	1	3.08	36.60	48.35	11.97	.78	......	......	......	......	1.3	......	......
				2	......	37.76	49.89	12.35	.80	......	......	......	......	......	......	......
				3	......	43.08	56.92	......	.91	......	......	......	......	......	......	......
Same (face of room 20, off east entry 7; 4,200 feet southeast of mouth of main entry).	237	12337	A	1	2.87	35.27	47.20	14.66	.48	......	......	......	......	1.0	......	......
				2	......	36.31	48.60	15.09	.49	......	......	......	......	......	......	......
				3	......	42.76	57.24	......	.58	......	......	......	......	......	......	......
Same (composite of samples 12335, 12336, and 12337).	237	12338	A	1	3.64	36.10	48.26	12.00	.70	5.25	69.76	1.31	10.98	1.9	7,013	12,623
				2	......	37.46	50.09	12.45	.73	5.03	72.40	1.36	8.03	......	7,278	13,100
				3	......	42.79	57.21	......	.83	5.75	82.70	1.55	9.17	......	8,313	14,963
Same (end of west entry 9; 4,900 feet southwest of mouth of main entry; 6-foot 3-inch bed).	237	14796	B	1	2.34	35.87	49.94	11.85	.63	5.17	71.27	1.34	9.74	1.0	7,178	12,920
				2	......	36.73	51.14	12.13	.65	5.03	72.98	1.37	7.84	......	7,350	13,230
				3	......	41.80	58.20	......	.74	5.72	83.05	1.56	8.93	......	8,364	15,055
Sugarite, 7 miles northeast of Raton; NE. ¼ NE. ¼ sec. 9, T. 31 N., R. 24 E.; Sugarite No. 1 mine; Sugarite bed (in entry 1,500 feet southwest of mine mouth, 5-foot 6½-inch bed, 5-foot 1-inch cut).	238	14791	B	1	3.83	38.12	49.12	8.93	.56	5.71	72.37	1.58	10.85	2.1	7,263	13,073
				2	......	39.64	51.07	9.29	.58	5.49	75.25	1.64	7.75	......	7,552	13,594
				3	......	43.70	56.30	......	.64	6.05	82.96	1.81	8.54	......	8,325	14,985
7 miles northeast of; NE. ¼ NW. ¼ sec. 3, T. 31 N., R. 24 E.; Sugarite No. 2 mine; Sugarite bed (in entry 1,200 feet northeast of mine mouth, 5-foot 7-inch bed, 4-foot 9-inch cut).	238	14792	B	1	2.91	39.72	48.67	8.70	.51	5.62	73.52	1.57	10.08	1.0	7,380	13,284
				2	......	40.91	50.13	8.96	.53	5.46	75.73	1.62	7.70	......	7,601	13,682
				3	......	44.94	55.06	......	.58	6.00	83.18	1.78	8.46	......	8,349	15,028
Yankee; Yankee No. 3 mine, Yankee bed (face of room 2, off west entry 10, 5-foot 9½-inch bed, 4-foot 7-inch cut.)	238	13365	A	1	5.21	36.99	48.25	9.55	.56	......	......	......	......	3.4	......	......
				2	......	39.02	50.90	10.08	.59	......	......	......	......	......	......	......
				3	......	43.39	56.61	......	.66	......	......	......	......	......	......	......
Same (face of south entry 5, 6-foot 3¼ inch bed, 4-foot 7-inch cut).	238	13366	A	1	6.05	35.23	42.10	16.62	.53	......	......	......	......	4.4	......	......
				2	......	37.50	44.81	17.69	.56	......	......	......	......	......	......	......
				3	......	45.56	54.44	......	.68	......	......	......	......	......	......	......

Same (composite of samples 13365 and 13366)......	239	13367	A	1	5.58	35.78	45.47	13.17	.55	5.31	66.76	1.18	13.03	3.9	6,677	12,019
				2	....	37.89	48.16	13.95	.58	4.97	70.71	1.25	8.54	....	7,072	12,730
				3	....	44.03	55.97	....	.67	5.78	82.17	1.45	9.93	....	8,218	14,792
LINCOLN COUNTY.																
White Oaks, 2 miles southeast of; SW. ¼ sec. 32, T. 6 S., R. 13 E., Wildcat mine (at foot of main slope, 25-inch bed, 21½-inch cut).	239	15054	B	1	2.52	34.63	45.99	16.86	.76	4.97	66.65	1.32	9.44	1.3	6,642	11,956
				2	....	35.53	47.17	17.30	.78	4.81	68.38	1.35	7.38	....	6,814	12,265
				3	....	42.96	57.04	....	.94	5.82	82.69	1.63	8.92	....	8,239	14,830
2½ miles southeast of; NW. ¼ sec. 5, T. 7 S., R. 13 E.; Old Abe mine, Old Abe bed (4-foot ½-inch bed and cut).	239	15053	B	1	2.49	37.86	44.95	14.70	.83	5.15	68.06	1.23	10.03	.9	6,813	12,263
				2	....	38.83	46.10	15.07	.85	4.99	69.80	1.26	8.03	....	6,987	12,577
				3	....	45.72	54.28	....	1.00	5.88	82.18	1.48	9.46	....	8,226	14,807
M'KINLEY COUNTY.																
Blackrock, 10 miles northeast of; sec. 6, T. 11 N., R. 17 W.; Zuni Indian School mine (room 2, west of the main entry, 3-foot 2-inch bed, 2-foot 10-inch cut).	240	15032	B	1	14.69	34.93	41.56	8.82	.79	5.82	60.93	1.12	22.52	11.0	6,005	10,809
				2	....	40.94	48.72	10.34	.93	4.91	71.42	1.31	11.09	....	7,039	12,670
				3	....	45.66	54.34	....	1.04	5.48	79.65	1.46	12.37	....	7,851	14,132
SANTA FE COUNTY.																
Madrid, Anthracite No. 4 mine, White Ash bed (at face, 1,500 feet southeast of mouth of main entry, 2-foot 9-inch bed and cut).	240	14886	B	1	7.55	7.25	75.88	9.32	.76	2.10	78.97	1.00	7.85	2.2	6,723	12,101
				2	....	7.84	82.08	10.08	.82	1.36	85.42	1.08	1.24	....	7,272	13,090
				3	....	8.72	91.28	....	.91	1.51	95.00	1.20	1.38	....	8,087	14,557
Blacksmith mine, Peacock (?) bed (at face, 310 feet south of mine mouth, 5-foot 3-inch bed, 2-foot 4-inch cut).	241	14884	B	1	4.62	26.44	61.34	7.60	1.27	5.22	75.94	1.38	8.59	3.8	7,519	13,534
				2	....	27.72	64.31	7.97	1.33	4.94	79.62	1.45	4.69	....	7,883	14,189
				3	....	30.12	69.88	....	1.45	5.37	86.52	1.58	5.08	....	8,566	15,419
Holen mine, Cook & White bed (at face, 1,300 feet northeast of mine mouth, 3-foot 5-inch bed, 3-foot 3-inch cut).	241	14885	B	1	3.65	35.05	49.47	11.83	.96	5.04	69.89	1.29	10.99	1.6	6,863	12,353
				2	....	36.38	51.34	12.28	1.00	4.81	72.54	1.34	8.03	....	7,123	12,821
				3	....	41.47	58.53	....	1.14	5.48	82.70	1.53	9.15	....	8,120	14,616
Peacock prospect, Peacock bed (at face, 400 feet northeast of entry mouth, 2-foot 4-inch bed and cut).	242	14887	B	1	3.16	41.37	44.46	11.01	1.59	5.28	69.71	1.24	11.17	.9	6,918	12,452
				2	....	42.72	45.91	11.37	1.64	5.09	71.98	1.28	8.64	....	7,144	12,859
				3	....	48.20	51.80	....	1.85	5.74	81.22	1.44	9.75	....	8,061	14,510
NORTH DAKOTA.																
ADAMS COUNTY.																
Haynes, 3½ miles northeast of; sec. 16, T. 129 N., R. 94 W.; Nipper & Monroe mine, Haynes bed (in mine, 634 feet east of mine mouth, 8-foot 3-inch cut).	242	*14542	B	1	32.65	30.57	28.49	8.29	1.53	....	....	....	....	14.5	4,087	7,357
				2	....	45.39	42.30	12.31	2.27	....	....	....	....	....	6,068	10,922
				3	....	51.76	48.24	....	2.59	....	....	....	....	....	6,920	12,456
9 miles northeast of; sec. 36, T. 130 N., R. 94 W.; William Pinkham mine, Haynes bed (225 feet south of entry mouth, 12-foot bed, 8-foot 10-inch cut).	242	*14544	B	1	32.43	30.89	28.11	8.57	1.49	....	....	....	....	15.3	4,071	7,328
				2	....	45.71	41.61	12.68	2.21	....	....	....	....	....	6,025	10,845
				3	....	52.35	47.65	....	2.53	....	....	....	....	....	6,900	12,420
BOWMAN COUNTY.																
Amor, 2 miles southeast of; sec. 34, T. 130 N., R. 103 W.; Durkin prospect, T Cross bed (face of pit, fresh cut, 8-foot 7½-inch bed, 2-foot 7½-inch cut).	242	*14857	B	1	43.63	23.24	26.95	6.18	.65	....	....	....	....	35.8	3,238	5,828
				2	....	41.23	47.81	10.96	1.15	....	....	....	....	....	5,744	10,339
				3	....	46.31	53.69	....	1.29	....	....	....	....	....	6,451	11,612
Scranton; sec. 24, T. 131 N., R. 100 W.; Scranton mine, Harmon (?) bed (face of main east entry off main entry; 500 feet from the main entry and 1,000 feet from portal, 20-foot 3½-inch bed, 6-foot cut).	243	*14485	B	1	34.80	31.09	25.98	8.13	.66	....	....	....	....	22.5	3,842	6,916
				2	....	47.68	39.85	12.47	1.01	....	....	....	....	....	5,892	10,606
				3	....	54.47	45.53	....	1.15	....	....	....	....	....	6,732	12,118

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
NORTH DAKOTA—Continued.																
MORTON COUNTY.																
Leith, 1½ miles west of; sec. 12, T. 133 N., R. 88 W.; Jones mine (in mine, about 75 feet southwest of the shaft, 5-foot 6-inch cut).	244	*14729	B	1	36.18	29.77	25.35	8.70	0.68	6.76	39.45	0.59	43.82	27.1	3,722	6,700
				2	....	46.65	39.72	13.63	1.07	4.29	61.81	0.92	18.28	....	5,832	10,498
				3	....	54.01	45.99	....	1.24	4.97	71.56	1.07	21.16	....	6,752	12,154
WARD COUNTY.																
Plaza, 25 miles west of; sec. 17, T. 152 N., R. 92 W.; prospect No. 3 bed (4-foot 11-inch bed, 3-foot 3-inch cut).	244	*11294	B	1	41.00	24.88	27.54	6.58	.44	....	....	....	....	33.7	3,266	5,879
				2	....	42.17	46.68	11.15	.75	....	....	....	....	....	5,536	9,965
				3	....	47.46	52.54	....	.84	....	....	....	....	....	6,231	11,216
WILLIAMS COUNTY.																
Avoca, ½ mile northeast of, 5 miles northeast of Williston; NW. ¼ sec. 3, T. 154 N., R. 100 W.; Bruegger mine, C bed (50 feet west of end of main entry and 1,225 feet northwest of mine mouth, 11-foot bed, 5-foot 6-inch cut).	244	*12587	B	1	41.53	26.97	27.18	4.32	.30	....	....	....	....	33.2	3,578	6,440
				2	....	46.13	46.48	7.39	.51	....	....	....	....	....	6,119	11,014
				3	....	49.81	50.19	....	.55	....	....	....	....	....	6,607	11,893
Trenton, 6 miles northeast of; sec. 27, T. 154 N., R. 102 W.; Geltz mine (at end of main entry, about 150 feet from mine mouth, 5-foot 6-inch bed, 5-foot 1-inch cut).	245	* 12411	B	1	42.71	25.70	24.77	6.82	1.38	....	....	....	....	34.7	3,368	6,062
				2	....	44.86	43.24	11.90	2.41	....	....	....	....	....	5,879	10,582
				3	....	50.92	49.08	....	2.74	....	....	....	....	....	6,673	12,011
Williston, 3½ miles southeast of; sec. 33, T. 154 N., R. 100 W.; Powell mine, C bed (50 feet north of main entry, about 900 feet northeast of mine mouth, 10-foot bed, 6-foot 6-inch cut).	245	* 12588	B	1	42.91	26.81	24.98	5.30	.71	....	....	....	....	34.7	3,462	6,232
				2	....	46.96	43.76	9.28	1.24	....	....	....	....	....	6,064	10,915
				3	....	51.76	48.24	....	1.37	....	....	....	....	....	6,684	12,031
2 miles north and 1 mile east of; sec. 7, T. 154 N., R. 100 W.; B bed, U. S. Reclamation Service mine (William Spangler's room, 50 feet north of main entry and 1,225 feet east of portal, 10-foot 3-inch bed, 8-foot cut).	245	* 12533	B	1	43.87	24.88	25.43	5.82	.49	....	....	....	....	33.2	3,299	5,938
				2	....	44.33	45.30	10.37	.87	....	....	....	....	....	5,877	10,579
				3	....	49.46	50.54	....	.97	....	....	....	....	....	6,557	11,808

OHIO.

JEFFERSON COUNTY.

Amsterdam, about 1 mile south of; sec. 18, T. 11 N., R. 4 W., Amsterdam mine, Lower Freeport (?), locally known as No. 7 bed (center of face of face entry, 5-foot 2-inch bed, 4-foot 1-inch cut).	246	10533	A	1	3.36	37.56	52.06	7.02	2.40	......	......	......	......	1.4	......	......
				2	......	38.87	53.87	7.26	2.48	......	......	......	......	......	......	......
				3	......	41.91	58.09	......	2.67	......	......	......	......	......	......	......
Same (room 4 off entry 4, east section, 1,000 feet northeast of shaft, 5-foot 7½-inch bed, 3-foot 9-inch cut).	246	15388	B	1	3.66	37.43	51.23	7.68	3.07	......	......	......	......	1.6	7,342	13,216
				2	......	38.85	53.18	7.97	3.19	......	......	......	......	......	7,621	13,718
				3	......	42.21	57.79	......	3.47	......	......	......	......	......	8,281	14,906
Same (room 15, west entry 9, section 2 north, 4,000 feet northwest of shaft; 5-foot 2½-inch bed, 3-foot 4-inch cut).	246	15389	B	1	3.52	38.31	50.78	7.39	2.99	......	......	......	......	1.4	7,363	13,253
				2	......	39.71	52.63	7.66	3.10	......	......	......	......	......	7,632	13,738
				3	......	43.01	56.99	......	3.36	......	......	......	......	......	8,265	14,877
Same (west entry 8, section 3 south, 4,500 feet southwest of shaft; 5-foot 3½-inch bed, 3-foot 5½-inch cut).	246	15390	B	1	3.27	38.87	50.37	7.49	3.23	......	......	......	......	1.2	7,359	13,246
				2	......	40.18	52.08	7.74	3.34	......	......	......	......	......	7,608	13,694
				3	......	43.55	56.45	......	3.63	......	......	......	......	......	8,246	14,843
Same (composite of samples 15388, 15389, and 15390).	246	15394	B	1	3.50	37.98	51.08	7.44	3.09	5.43	73.39	1.46	9.19	1.4	7,381	13,286
				2	......	39.36	52.93	7.71	3.20	5.22	76.05	1.51	6.31	......	7,649	13,768
				3	......	42.65	57.35	......	3.47	5.66	82.40	1.64	6.83	......	8,288	14,918
Halfway between Bergholz and; sec. 8, T. 12 N., R. 4 W.; Eastern Ohio mine, Lower Freeport (?) bed (room 11, off west butt entry 12, 3,000 feet west of mouth of slope, 5-foot 4-inch bed, 4-foot 8-inch cut).	247	15391	B	1	3.58	37.58	49.17	9.67	3.08	......	......	......	......	1.5	7,156	12,881
				2	......	38.97	51.00	10.03	3.19	......	......	......	......	......	7,421	13,358
				3	......	43.32	56.68	......	3.55	......	......	......	......	......	8,248	14,846
Same (face of west entry 13, off south face entry, 4-foot 9-inch cut).	247	15392	B	1	3.47	38.61	49.66	8.26	2.40	......	......	......	......	1.5	7,346	13,223
				2	......	40.00	51.44	8.56	2.49	......	......	......	......	......	7,610	13,698
				3	......	43.74	56.26	......	2.72	......	......	......	......	......	8,322	14,980
Same (left butt entry 12, off north face entry, 2,700 feet northeast of mouth of slope, 5-foot 4½-inch bed, 4-foot 11-inch cut).	247	15393	B	1	4.04	38.61	48.93	8.42	2.95	......	......	......	......	2.0	7,234	13,021
				2	......	40.24	50.99	8.77	3.07	......	......	......	......	......	7,539	13,570
				3	......	44.11	55.89	......	3.37	......	......	......	......	......	8,263	14,873
Same (composite of samples 15391, 15392, and 15393).	247	15395	B	1	3.69	37.97	49.59	8.75	2.82	5.32	71.76	1.39	9.96	1.7	7,283	13,109
				2	......	39.42	51.49	9.09	2.93	5.10	74.51	1.44	6.93	......	7,562	13,612
				3	......	43.36	56.64	......	3.22	5.61	81.96	1.58	7.63	......	8,318	14,972
2 miles east of; sec. 7, T. 12 N., R. 4 W.; Elizabeth mine, Lower Freeport (?) bed (room 22, off west entry 3, 2,600 feet northwest of shaft; 4-foot 5½-inch bed, 3-foot 9-inch cut).	247	15440	B	1	3.40	38.01	52.37	6.22	2.20	......	......	......	......	1.7	7,518	13,532
				2	......	39.35	54.21	6.44	2.28	......	......	......	......	......	7,783	14,009
				3	......	42.06	57.94	......	2.44	......	......	......	......	......	8,318	14,972
Same (room 33, off second south face entry, 2,400 feet west of shaft, 5-foot 5½-inch bed, 4-foot 1-inch cut).	247	15441	B	1	3.50	37.93	50.63	7.94	3.14	......	......	......	......	1.4	7,364	13,255
				2	......	39.31	52.46	8.23	3.25	......	......	......	......	......	7,631	13,736
				3	......	42.84	57.16	......	3.54	......	......	......	......	......	8,316	14,969
Same (composite of samples 15440 and 15441).....	247	15442	B	1	3.38	38.01	51.64	6.97	2.71	5.40	73.31	1.46	10.15	1.6	7,438	13,388
				2	......	39.34	53.45	7.21	2.80	5.20	75.88	1.51	7.40	......	7,698	13,856
				3	......	42.40	57.60	......	3.02	5.60	81.78	1.63	7.97	......	8,296	14,933
Same, Lower Freeport (?) bed (room 6, off west entry 9, 2,600 feet north of shaft, 4-foot 7½-inch bed, 3-foot 10½-inch cut).	247	15443	B	1	3.59	37.03	50.64	8.74	3.70	5.19	71.30	1.39	9.68	1.8	7,224	13,003
				2	......	38.41	52.52	9.07	3.84	4.97	73.95	1.44	6.73	......	7,493	13.487
				3	......	42.24	57.76	......	4.22	5.47	81.32	1.58	7.41	......	8,240	14,832

***Table of chemical analyses*—Continued.**

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
OHIO—Continued.																
JEFFERSON COUNTY—continued.																
Brilliant, 1½ miles northwest of; sec. 6, T. 5 N., R. 2 W.; Goucher No. 2 mine, Pittsburgh or No. 8 bed (face of entry 2, north side of mine, 500 feet northwest of opening, 4-foot 9½-inch bed, 4-foot 5½-inch cut).	248	15563	B	1	3.79	38.78	50.03	7.40	3.84					2.0	7,267	13,081
				2		40.31	52.00	7.69	3.99						7,553	13,595
				3		43.67	56.33		4.32						8,182	14,728
Same (room 1 off right entry 1, 500 feet northwest of opening; 5-foot 3½-inch bed, 4-foot 8-inch cut).	248	15564	B	1	4.28	37.41	50.29	8.02	3.72					2.5	7,201	12,962
				2		39.08	52.54	8.38	3.89						7,523	13,541
				3		42.66	57.34		4.25						8,211	14,780
Same (composite of samples 15563 and 15564).....	248	15565	B	1	4.11	37.96	50.23	7.70	3.84	5.23	71.69	1.39	10.15	2.3	7,230	13,014
				2		39.59	52.38	8.03	4.00	4.97	74.77	1.45	6.78		7,540	13,572
				3		43.05	56.95		4.35	5.40	81.30	1.58	7.37		8,129	14,756
Hopedale, 2 miles southeast of; sec. 32, T. 9 N., R. 3 W.; Parlett mine, Pittsburgh or No. 8 bed (room 9, off west entry 2 off south entry, 2,200 feet northeast of the mouth of the slope; 5-foot 11½-bed, 4-foot 6-inch cut).	248	15444	B	1	5.01	36.15	52.83	6.01	1.74					2.2	7,327	13,189
				2		38.06	55.61	6.33	1.83						7,713	13,883
				3		40.63	59.37		1.95						8,234	14,821
Same (in north entry 2, 180 feet beyond rooms 9 and 10, off west entry, 400 feet northwest of the mouth of the slope; 7-foot 11-inch bed, 4-foot 5-inch cut).	248	15445	B	1	4.32	37.09	49.14	9.45	3.82					2.6	7,072	12,730
				2		38.76	51.36	9.88	3.99						7,391	13,304
				3		43.01	56.99		4.43						8,201	14,762
Same (composite of samples 15444 and 15445).....	248	15446	B	1	4.66	36.63	50.82	7.89	2.80	5.28	71.72	1.35	10.96	2.4	7,193	12,947
				2		38.42	53.30	8.28	2.94	4.99	75.23	1.42	7.14		7,545	13,581
				3		41.89	58.11		3.21	5.44	82.02	1.55	7.78		8,226	14,807
Piney Fork, 2 miles southwest of Smithfield; sec. 16, T. 8 N., R. 3 W.; Cabbage Run mine; Pittsburgh bed (room 26, left entry 3, 1,050 feet northeast of mine mouth, 4-foot 8-inch bed, 4-foot 1-inch cut).	249	15491	B	1	5.45	35.73	54.22	4.60	.84					3.2	7,401	13,322
				2		37.79	57.35	4.86	.89						7,827	14,089
				3		39.72	60.28		.94						8,227	14,809

Two miles southwest of Smithfield; sec. 21, T. 8 N., R. 3 W.; Piney Fork No. 1 mine, Pittsburgh bed (room 14 off left entry off main east entry, 4,000 feet southwest of mine mouth, 4-foot 9½-inch, bed, 4-foot 1½-inch cut).	249	15489	B	1	4.87	36.63	51.25	7.25	2.60	5.36	71.91	1.38	11.50	2.8	7,218	12,992
				2		38.51	53.87	7.62	2.73	5.07	75.59	1.45	7.54		7,588	13,658
				3		41.69	58.31		2.96	5.49	81.83	1.57	8.15		8,214	14,785
Two miles southwest of Smithfield; sec. 17, T. 8 N., R. 3 W.; Piney Fork No. 2 mine, Pittsburgh bed (room 28, off east entry 21, 5,600 feet northeast of mine mouth, 4-foot 5½-inch bed, 3-foot 10½-inch cut).	249	15490	B	1	5.47	35.77	53.28	5.48	.77					3.2	7,324	13,183
				2		37.84	56.36	5.80	.81						7,748	13,946
				3		40.17	59.83		.86						8,225	14,805
Smithfield, 2 miles east of; sec. 29, T. 5 N., R. 2 W.; Plumb Run No. 1 mine, Pittsburgh bed (room 7, east entry 7, south face entry, 2,500 feet northeast of mine mouth; 4-foot 9-inch bed, 4-foot 6-inch cut).	250	15486	B	1	4.78	35.93	53.98	5.31	.98	5.35	74.13	1.46	12.77	2.6	7,417	13,351
				2		37.73	56.69	5.58	1.03	5.06	77.85	1.53	8.95		7,789	14,020
				3		39.96	60.04		1.09	5.36	82.45	1.62	9.48		8,249	14,848
Two miles east of; sec. 30, T. 5 N., R. 2 W.; Plumb Run No. 4 mine, Pittsburgh or No. 8 bed (room 14, off right entry 15, 4,400 feet northeast of mine mouth, 4-foot 4½-inch bed, 4-foot 1-inch cut.)	250	15487	B	1	4.52	36.40	51.10	7.98	3.33					2.6	7,157	12,883
				2		38.12	53.52	8.36	3.49						7,496	13,493
				3		41.60	58.40		3.81						8,180	14,724
Two miles east of; sec. 29, T. 5 N., R 2 W; Plumb Run No. 5 mine, Pittsburgh or No. 8 bed (room 3, right entry 2, off first right face entry, 1,800 feet southeast of mine mouth, 4-foot 6½-inch bed, 4-foot 3½-inch cut).	250	15488	B	1	4.26	36.61	52.18	6.95	2.57					2.3	7,307	13,153
				2		38.24	54.50	7.26	2.68						7,632	13,738
				3		41.23	58.77		2.89						8,230	14,814
Steubenville, sec. 29, T. 2 N., R. 1 W.; La Belle mine, Lower Freeport bed (fifth south butt entry, off southeast entry, 4,400 feet southeast of shaft, 3-foot 4½-inch bed, 3-foot 1½-inch cut).	250	15676	B	1	3.80	35.39	53.39	7.42	1.91					1.5	7,344	13,219
				2		36.79	55.50	7.71	1.99						7,634	13,741
				3		39.86	60.14		2.16						8,271	14,888
Same (in room 9, off left entry, off second south butt entry, 5,200 feet southeast from shaft, 3-foot 2-inch bed, 3-foot ¾-inch cut).	250	15675	B	1	3.82	35.90	53.43	6.85	1.90	5.24	74.20	1.45	10.36	1.6	7,418	13,352
				2		37.33	55.55	7.12	1.98	5.01	77.15	1.51	7.23		7,712	13,882
				3		40.19	59.81		2.13	5.39	83.07	1.63	7.78		8,304	14,947
NOBLE COUNTY.																
Belle Valley, 1 mile northwest of; Noble mine, No. 7 bed (face of south entry 8 (motor road) 5,700 feet southwest of shaft bottom, 4-foot 3½-inch bed, 4-foot ½-inch cut).	251	17213	A	1	4.88	37.76	48.93	8.43	2.95					1.4	7,073	12,731
				2		39.70	51.44	8.86	3.10						7,436	13,385
				3		43.56	56.44		3.40						8,159	14,686
Same (face of room 5, off south entry 7, 5,600 feet southwest of shaft bottom, 5-foot 4-inch bed, 5-foot 2-inch cut).	251	17214	A	1	5.13	37.17	49.59	8.11	2.99					1.5	7,053	12,695
				2		39.18	52.27	8.55	3.15						7,435	13,383
				3		42.85	57.15		3.44						8,130	14,634
Same (composite of samples 17213 and 17214).....	251	17215	A	1	5.15	37.34	49.00	8.51	2.94	5.42	70.51	1.50	11.12	1.5	7,074	12,733
				2		39.37	51.66	8.97	3.10	5.12	74.34	1.58	6.89		7,459	13,426
				3		43.25	56.75		3.41	5.62	81.66	1.74	7.57		8,194	14,749

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
OKLAHOMA.																
HASKELL COUNTY.																
McCurtain, 1 mile west of; San Bois No. 2 mine; McCurtain (Hartshorne) bed (face of south entry 13; 5,000 feet west of slope mouth, 8-foot ⅜-inch bed, 5-foot 8¼-inch cut).	252	13688	A	1	2.44	20.77	69.84	6.95	1.15	......	......	......	......	1.7	......	......
				2	......	21.29	71.59	7.12	1.18	......	......	......	......	......	......	......
				3	......	22.92	77.08	......	1.27	......	......	......	......	......	......	......
Same (face of room 3 off north entry 13, top side; 5,000 feet west of slope mouth, 7-foot 3⅝-inch bed, 5-foot 7¾-inch cut).	252	13689	A	1	2.57	20.29	71.21	5.93	.83	......	......	......	......	1.8	......	......
				2	......	20.83	73.08	6.09	.85	......	......	......	......	......	......	......
				3	......	22.18	77.82	......	.91	......	......	......	......	......	......	......
Same (face of south entry 11, 50 feet from slope and 5,000 feet west of slope mouth, 6-foot 10-inch bed, 5-foot 6-inch cut).	252	13690	A	1	3.21	21.78	68.84	6.17	.59	......	......	......	......	2.2	......	......
				2	......	22.50	71.13	6.37	.61	......	......	......	......	......	......	......
				3	......	24.03	75.97	......	.65	......	......	......	......	......	......	......
Same (face of south entry 12, top side; 5,500 feet west of slope mouth, 8-foot 11¼-inch bed, 5-foot 8¾-inch cut).	252	13691	A	1	2.81	20.79	70.65	5.75	.56	......	......	......	......	2.0	......	......
				2	......	21.39	72.69	5.92	.58	......	......	......	......	......	......	......
				3	......	22.74	77.26	......	.62	......	......	......	......	......	......	......
Same (neck of room 6, off north entry 12, top side; 5,300 feet west of slope mouth, 6-foot 6-inch bed, 5-foot 4-inch cut).	252	13692	A	1	2.92	21.44	68.80	6.84	.76	......	......	......	......	2.0	......	......
				2	......	22.09	70.86	7.05	.78	......	......	......	......	......	......	......
				3	......	23.76	76.24	......	.84	......	......	......	......	......	......	......
Same (composite of samples 13688, 13689, 13690, 13691, and 13692).	252	13693	A	1	2.70	21.07	69.88	6.35	.77	4.46	81.33	1.67	5.42	1.9	7,832	14,098
				2	......	21.65	71.82	6.53	.79	4.28	83.58	1.72	3.10	......	8,049	14,488
				3	......	23.16	76.84	......	.85	4.58	89.42	1.84	3.31	......	8,612	15.502
PITTSBURG COUNTY.																
Adamson, 1¼ miles east of; sec. 9, T. 5 N., R. 17 E.; Eclipse No. 1 mine, Lower Hartshorne bed (face of east entry 3, 600 feet northeast of slope mouth, 4-foot 6-inch bed and cut).	252	16143	A	1	5.18	35.61	55.22	3.99	1.14	......	......	......	......	3.8	......	......
				2	......	37.55	58.24	4.21	1.20	......	......	......	......	......	......	......
				3	......	39.20	60.80	......	1.25	......	......	......	......	......	......	......
Same (face of west entry 3; 600 feet northwest of slope mouth; 4-foot bed and cut).	253	16144	A	1	4.39	36.33	55.35	3.93	1.57	......	......	......	......	3.0	......	......
				2	......	38.00	57.89	4.11	1.64	......	......	......	......	......	......	......
				3	......	39.63	60.37	......	1.71	......	......	......	......	......	......	......
Same (composite of samples 16143 and 16144).....	253	16145	A	1	4.83	35.76	55.55	3.86	1.34	5.57	77.08	1.97	10.18	3.4	7.683	13,829
				2	......	37.58	58.36	4.06	1.41	5.29	81.00	2.07	6.17	......	8,073	14,531
				3	......	39.17	60.83	......	1.47	5.51	84.43	2.16	6.43	......	8,414	15,145

Alderson, 1½ miles southwest of; sec. 15, T. 5 N., R. 15 E.: Alderson No. 5 mine, McAlester bed (face of room 1, off fourth west back entry, off west slope, 2,200 feet west of shaft, 3-foot 7-inch bed and cut).	253	11915	A	1	2.81	36.37	56.35	4.47	.75	....	....	....	....	1.1	....	....
				2	....	37.42	57.98	4.60	.77	....	....	....	....	....	....	....
				3	....	39.22	60.78	....	.81	....	....	....	....	....	....	....
Same (face of room 7, off west entry 7, off west slope, 2,800 feet northwest of shaft, 3-foot 5-inch bed and cut).	253	11916	A	1	3.17	35.28	57.39	4.16	.58	....	....	....	....	1.3	....	....
				2	....	36.43	59.27	4.30	.60	....	....	....	....	....	....	....
				3	....	38.07	61.93	....	.63	....	....	....	....	....	....	....
Same (face of room 66, off east entry 11, off east slope, 4,000 feet east of shaft, 3-foot 4-inch bed, 2-foot 6-inch cut).	253	11917	A	1	3.25	34.55	57.59	4.61	.59	....	....	....	....	1.3	....	....
				2	....	35.71	59.53	4.76	.61	....	....	....	....	....	....	....
				3	....	37.50	62.50	....	.64	....	....	....	....	....	....	....
Same (face of west entry 2, off east slope, about 2,000 feet southeast of shaft, 3-foot 7-inch bed and cut).	253	11918	A	1	2.97	35.78	56.82	4.43	.64	....	....	....	....	1.2	....	....
				2	....	36.87	58.56	4.57	.66	....	....	....	....	....	....	....
				3	....	38.64	61.36	....	.69	....	....	....	....	....	....	....
Same (composite of samples 11915, 11916, 11917, and 11918).	253	11919	A	1	3.07	35.26	57.30	4.37	.62	5.45	78.31	1.70	9.55	1.2	7,762	13,972
				2	....	36.38	59.11	4.51	.64	5.27	80.79	1.75	7.04	....	8,008	14,414
				3	....	38.10	61.90	....	.67	5.52	84.60	1.83	7.38	....	8,386	15,095
2 miles east of; T. 5 N., R. 15 E.; Alderson No. 38 mine, McAlester bed (room 1, off west entry 7, 2,200 feet down main slope, 2-foot 9-inch bed and cut).	254	11592	A	1	3.19	32.71	57.06	7.04	.50	5.23	75.57	1.62	10.04	1.7	7,486	13,475
				2	....	33.79	58.94	7.27	.52	5.04	78.06	1.67	7.44	....	7,733	13,919
				3	....	36.44	63.56	....	.56	5.44	84.20	1.80	8.00	....	8,339	15,010
Same (room 4, off east entry 5, 2,300 feet down main slope, 3-foot 3-inch bed and cut).	254	11594	A	1	3.57	33.38	58.05	5.00	.49	5.34	77.37	1.66	10.14	2.0	7,634	13,741
				2	....	34.62	60.19	5.19	.51	5.12	80.23	1.72	7.23	....	7,916	14,249
				3	....	36.51	63.49	....	.54	5.40	84.63	1.81	7.62	....	8,349	15,028
Same (room 26, off east entry 4, 1,900 feet down main slope, 3-foot 6-inch bed and cut).	254	11670	A	1	3.22	34.84	57.21	4.73	.48	5.25	78.18	1.73	9.63	1.3	7,707	13,873
				2	....	36.00	59.11	4.89	.50	5.05	80.78	1.79	6.99	....	7,964	14,335
				3	....	37.85	62.15	....	.53	5.31	84.93	1.88	7.35	....	8,373	15,071
Same (face of east entry 6, 3-foot 6-inch bed and cut).	254	15188	A	1	2.84	35.71	55.93	5.52	.61	5.38	77.69	1.89	8.91	1.2	7,654	13,777
				2	....	36.75	57.57	5.68	.63	5.21	79.96	1.95	6.57	....	7,877	14,179
				3	....	38.96	61.04	....	.67	5.52	84.77	2.07	6.97	....	8,351	15,032
Same (face of west air course 7, 3-foot 9-inch bed and cut).	254	15189	A	1	3.21	35.65	56.50	4.64	.67	5.28	77.43	1.85	10.13	1.5	7,694	13,849
				2	....	36.83	58.38	4.79	.69	5.08	80.00	1.91	7.53	....	7,949	14,308
				3	....	38.68	61.32	....	.72	5.34	84.02	2.01	7.91	....	8,349	15,028
Craig, Bolen-Darnall No. 4 mine, McAlester bed (face of eighth west entry, 3,000 feet northwest of mine mouth, 2-foot 11½-inch bed, 2-foot 10½-inch cut).	254	15104	A	1	3.51	36.23	55.09	5.17	.82	....	....	....	....	1.7	7,531	13,556
				2	....	37.55	57.09	5.36	.85	....	....	....	....	....	7,805	14,049
				3	....	39.68	60.32	....	.90	....	....	....	....	....	8,247	14,845
Same (face of eighth east entry, 3,000 feet from mine mouth, 3-foot ½-inch bed and cut).	254	15105	A	1	3.57	36.06	55.15	5.22	.86	....	....	....	....	1.7	7,536	13,565
				2	....	37.39	57.20	5.41	.89	....	....	....	....	....	7,815	14,067
				3	....	39.53	60.47	....	.94	....	....	....	....	....	8,262	14,872
McAlester, 2 miles east of, sec. 32, T. 6 N., R. 15 E.; Busby No. 5 mine, McAlester bed (room 11, off west entry 3, off east slope, 1,600 feet from shaft, 4-foot 2-inch bed and cut).	255	11569	A	1	3.28	33.79	57.75	5.18	.54	5.20	77.96	1.69	9.43	1.9	7,576	13,637
				2	....	34.94	59.70	5.36	.56	5.00	80.60	1.75	6.73	....	7,833	14,099
				3	....	36.92	63.08	....	.59	5.28	85.16	1.85	7.12	....	8,276	14,897
Same (face of west entry 2, off west slope, 300 feet beyond room 26, 4-foot bed and cut).	255	11586	A	1	3.99	31.01	59.51	5.49	.56	....	....	....	....	2.4	....	....
				2	....	32.30	61.98	5.72	.58	....	....	....	....	....	....	....
				3	....	34.26	65.74	....	.62	....	....	....	....	....	....	....
Same (face of east entry 3, off east slope, 120 feet beyond room 22, 4-foot 2-inch bed and cut).	255	11587	A	1	3.56	32.94	57.93	5.57	.55	....	....	....	....	2.1	....	....
				2	....	34.16	60.06	5.78	.57	....	....	....	....	....	....	....
				3	....	36.25	63.75	....	.60	....	....	....	....	....	....	....

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
OKLAHOMA—Continued.																
PITTSBURG COUNTY—continued.																
McAlester, 2 miles east of, sec. 32, T. 6 N., R. 15 E., Busby No. 5 mine, McAlester bed (face of east entry 4, off west slope, 4-foot bed and cut).	255	11588	A	1	3.29	32.88	58.59	5.24	0.58	......	......	......	......	1.8	......	......
				2	......	34.00	60.58	5.42	.60	......	......	......	......	......	......	......
				3	......	35.95	64.05	......	.63	......	......	......	......	......	......	......
Same (face of east entry 5, off east slope, 4-foot 3-inch bed and cut).	255	11589	A	1	3.13	32.52	59.69	4.66	.52	......	......	......	......	1.8	......	......
				2	......	33.57	61.62	4.81	.54	......	......	......	......	......	......	......
				3	......	35.27	64.73	......	.57	......	......	......	......	......	......	......
Same (face of east entry 3, off west slope, 200 feet beyond room 8, 4-foot bed and cut).	255	11590	A	1	3.17	32.31	59.41	5.11	.61	......	......	......	......	1.7	......	......
				2	......	33.37	61.35	5.28	.63	......	......	......	......	......	......	......
				3	......	35.23	64.77	......	.67	......	......	......	......	......	......	......
Same (composite of samples 11586-11590).........	255	11591	A	1	3.58	32.11	59.04	5.27	.56	5.31	77.11	1.62	10.13	2.0	7,564	13,615
				2	......	33.31	61.22	5.47	.58	5.09	79.97	1.68	7.21	......	7,845	14,121
				3	......	35.24	64.76	......	.61	5.38	84.60	1.78	7.63	......	8,299	14,938
OREGON.																
COOS COUNTY.																
West Fork, 36 miles southwest of; NE. ¼ sec. 28, T. 32 S., R. 11 W.; Flanigan prospect, Anderson bed (in entry, 125 feet from mouth, 5-foot 6-inch bed, 5-foot 1½-inch cut).	255	14828	B	1	10.13	31.31	24.91	33.65	1.11	......	......	......	......	6.2	4,148	7,466
				2	......	34.84	27.72	37.44	1.24	......	......	......	......	......	4,615	8,307
				3	......	55.69	44.31	......	1.98	......	......	......	......	......	7,377	13,279
37 miles southwest of; SW. ¼ NE. ¼ sec. 29, T. 32 S., R. 11 W.; Hammond prospect, Carter bed (in entry, 100 feet from mouth, 6-foot bed, 4-foot 5-inch cut).	256	14831	B	1	8.05	34.98	37.12	19.85	.58	......	......	......	......	3.7	5,460	9,828
				2	......	38.04	40.37	21.59	.63	......	......	......	......	......	5,938	10,688
				3	......	48.52	51.48	......	.80	......	......	......	......	......	7,573	13,631
36 miles southwest of; SE. ¼ NE. ¼ sec. 32, T. 32 S., R. 11 W.; Hillis prospect, Anderson bed (in entry 90 feet from mouth, 6-foot 10-inch bed, 1-foot 3½-inch cut).	256	14827	B	1	9.97	38.45	36.35	15.23	.63	......	......	......	......	6.7	5,849	10,528
				2	......	42.71	40.37	16.92	.70	......	......	......	......	......	6,496	11,693
				3	......	51.41	48.59	......	.84	......	......	......	......	......	7,819	14,074
Same (in entry 90 feet from mouth, 6-foot 10-inch bed, 2-foot 9½-inch cut).	256	14830	B	1	6.71	35.51	27.41	30.37	2.22	......	......	......	......	3.3	4,750	8,550
				2	......	38.06	29.39	32.55	2.38	......	......	......	......	......	5,092	9,166
				3	......	56.43	43.57	......	3.53	......	......	......	......	......	7,549	13,588

38 miles southwest of; NW. ¼ NE. ¼ sec. 30, T. 32 S., R. 11 W.; Vanderpool prospect, Anderson bed (in entry, 217 feet from mouth, 5-foot 11½-inch bed, 1-foot 10-inch cut).	257	14829	B	1	7.28	37.63	27.56	27.53	2.59	......	......	......	......	3.3	4,917	8,851
				2	......	40.58	29.73	29.69	2.79	......	......	......	......	......	5,303	9,545
				3	......	57.72	42.28	......	3.97	......	......	......	......	......	7,542	13,576
MALHEUR COUNTY.																
Nyssa, 25 miles southwest of; NE. ¼ sec. 2, T. 22 S., R. 44 E. (unsurveyed); Honolulu prospect (at mouth of slope, 2-foot 4-inch bed, 8-inch cut).	257	*12585	B	1	30.31	19.03	18.86	31.80	2.66	......	......	......	......	20.7	2,431	4,376
				2	......	27.31	27.06	45.63	3.82	......	......	......	......	......	3,488	6,278
				3	......	50.23	49.77	......	7.03	......	......	......	......	......	6,415	11,547
PENNSYLVANIA.																
ALLEGHENY COUNTY.																
Bruceton, about 1 mile south of; near Wallace Station; Experimental mine, Pittsburgh bed (rib of first cross cut, 200 feet from mouth of air course, 5-foot 11-inch bed, 5-foot 7⅞-inch cut).	258	11983	A	1	3.11	35.16	55.95	5.78	1.17	......	......	......	......	1.3	......	......
				2	......	36.29	57.74	5.97	1.21	......	......	......	......	......	......	......
				3	......	38.59	61.41	......	1.29	......	......	......	......	......	......	......
Same (rib near face of air course, 390 feet from mouth of air course, 5-foot 7 1/16-inch bed, 5-foot 3-inch cut).	258	11984	A	1	2.68	35.37	55.76	6.19	1.48	......	......	......	......	1.0	......	......
				2	......	36.34	57.30	6.36	1.52	......	......	......	......	......	......	......
				3	......	38.81	61.19	......	1.62	......	......	......	......	......	......	......
Same (face of main entry, 345 feet from mouth of main entry, 5-foot 3-inch bed, 5-foot ¾-inch cut).	258	11985	A	1	2.65	35.49	55.18	6.68	1.49	......	......	......	......	1.0	......	......
				2	......	36.46	56.68	6.86	1.53	......	......	......	......	......	......	......
				3	......	39.15	60.85	......	1.64	......	......	......	......	......	......	......
Same (composite of samples 11983, 11984, and 11985).	258	11986	A	1	2.73	36.03	54.98	6.26	1.39	5.26	76.82	1.46	8.81	1.1	7,675	13,815
				2	......	37.04	56.52	6.44	1.43	5.10	78.98	1.50	6.55	......	7,891	14,204
				3	......	39.59	60.41	......	1.53	5.45	84.41	1.60	7.01	......	8,434	15,181
Same (in air course, 75 feet from outcrop at mouth of air course, 5-foot 11½-inch bed, 5-foot 10½-inch cut).	258	12251	A	1	2.87	35.21	57.56	4.36	1.15	5.37	78.49	1.56	9.07	0.9	7,800	14,040
				2	......	36.25	59.26	4.49	1.18	5.20	80.81	1.61	6.71	......	8,030	14,454
				3	......	37.95	62.05	......	1.24	5.44	84.61	1.69	7.02	......	8,407	15,133
Same (left side of air course, 150 feet from mouth of air course, 6-foot bed, 5-foot 10½-inch cut).	258	12262	A	1	3.34	35.16	56.91	4.59	1.42	5.38	77.51	1.51	9.59	1.4	7,764	13,975
				2	......	36.38	58.87	4.75	1.47	5.18	80.19	1.56	6.85	......	8,033	14,456
				3	......	38.20	61.80	......	1.54	5.44	84.19	1.64	7.19	......	8,434	15,181
Same (left side of air course, 430 feet from outcrop at mouth of air course, 5-foot 5-inch bed, 5-foot 2½-inch cut).	258	12264	A	1	2.87	35.12	55.84	6.17	1.52	5.34	77.04	1.53	8.40	0.9	7,644	13,759
				2	......	36.16	57.49	6.35	1.56	5.17	79.31	1.58	6.03	......	7,869	14,164
				3	......	38.61	61.39	......	1.67	5.52	84.69	1.69	6.43	......	8,403	15,125
Same (530 feet inby outcrop, right side of main entry, 5-foot 2¾-inch bed, 4-foot 9½-inch cut).	258	12569	A	1	3.32	36.82	54.19	5.67	1.03	5.32	76.94	1.53	9.51	1.3	7,635	13,743
				2	......	38.08	56.06	5.86	1.07	5.12	79.58	1.58	6.79	......	7,897	14,215
				3	......	40.45	59.55	......	1.14	5.44	84.53	1.68	7.21	......	8,388	15,098
Same (580 feet inby outcrop; right side of main entry, 5-foot 2-inch bed, 4-foot 10-inch cut).	258	12572	A	1	2.93	36.19	55.14	5.74	1.15	5.46	76.83	1.51	9.31	0.8	7,645	13,761
				2	......	37.28	56.81	5.91	1.18	5.28	79.15	1.56	6.92	......	7,876	14,177
				3	......	39.62	60.38	......	1.25	5.61	84.12	1.66	7.36	......	8,371	15,068
Same (630 feet inby outcrop; right side of main entry, 5-foot 2¾-inch bed, 5-foot ¾-inch cut).	258	12577	A	1	3.22	34.64	53.68	8.46	1.07	5.20	74.24	1.46	9.57	1.3	7,377	13,279
				2	......	35.79	55.47	8.74	1.11	5.00	76.71	1.51	6.93	......	7,623	13,721
				3	......	39.22	60.78	......	1.22	5.48	84.06	1.65	7.59	......	8,353	15,035
Same (680 feet inby outcrop; right side of main entry, 5-foot 4-inch bed and cut).	258	12557	A	1	3.30	36.09	53.46	7.15	1.17	5.36	74.58	1.53	10.21	1.3	7,509	13,516
				2	......	37.32	55.29	7.39	1.21	5.16	77.12	1.58	7.54	......	7,765	13,977
				3	......	40.30	59.70	......	1.31	5.57	83.27	1.71	8.14	......	8,385	15,093
Same (in crosscut, off main entry, at station E-1250, 3 feet from main entry, 5-foot 5½-inch bed, 5-foot 3-inch cut).	258	14797	A	1	3.34	35.49	54.54	6.63	1.24	......	......	......	......	1.9	......	......
				2	......	36.72	56.42	6.86	1.28	......	......	......	......	......	......	......
				3	......	39.43	60.57	......	1.37	......	......	......	......	......	......	......
Same (in main entry at station E-1270, 5 foot 7½ inch bed, 5-foot 2¾-inch cut).	258	14798	A	1	3.27	35.84	54.97	5.92	1.33	......	......	......	......	1.8	......	......
				2	......	37.05	56.83	6.12	1.37	......	......	......	......	......	......	......
				3	......	39.47	60.53	......	1.46	......	......	......	......	......	......	......

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.					Ultimate.				Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
ALLEGHENY COUNTY—continued.																
Creighton; Hite mine, Upper Freeport (E) and Lower Freeport (D) beds (face of room 17, butt entry 1, 8,000 feet west of mine mouth, 5-foot 10-inch bed, 4-foot 11-inch cut).	260	11130	A	1	2.69	34.80	55.99	6.52	0.96	....	....	....	....	1.2	....	....
				2	....	35.76	57.54	6.70	.99	....	....	....	....	....	....	....
				3	....	38.33	61.67	....	1.06	....	....	....	....	....	....	....
Same (face of room 18, butt entry 3, 9,000 feet from mine mouth, 5-foot 11-inch bed, 5-foot 3-inch cut).	260	11132	A	1	2.66	34.35	56.42	6.57	.99	....	....	....	....	1.2	....	....
				2	....	35.29	57.96	6.75	1.02	....	....	....	....	....	....	....
				3	....	37.84	62.16	....	1.09	....	....	....	....	....	....	....
Same (grab sample of cannel (roof) coal, at intersection of line entry and main entry 1, 1-foot 3-inch cut).	260	11133	A	1	1.12	26.17	36.45	36.26	1.58	....	....	....	....	0.4	....	....
				2	....	26.47	36.86	36.67	1.60	....	....	....	....	....	....	....
				3	....	41.80	58.20	....	2.53	....	....	....	....	....	....	....
Oak Station, short distance south of Pittsburgh; Oak mine, Pittsburgh bed (room 10, left entry 13, 5,300 feet north of mine mouth).	260	10845	A	1	3.48	35.15	55.45	5.92	1.18	5.42	75.73	1.45	10.30	1.7	7,611	13,700
				2	....	36.42	57.45	6.13	1.22	5.21	78.46	1.50	7.48	....	7,885	14,193
				3	....	38.80	61.20	....	1.30	5.55	83.58	1.60	7.97	....	8,400	15,120
BEDFORD COUNTY.																
Hopewell, 2 miles east of; Cambria No. 3 mine, Upper Freeport (locally known as Kelley) bed (face of heading 2, 7,300 feet northeast of shaft, 3-foot 11½-inch bed and cut).	261	15057	A	1	....	....	....	....	....	....	....	....	....	....	....	....
				2	....	17.08	70.50	12.42	2.26	....	....	....	....	....	7,594	13,669
				3	....	19.50	80.50	....	2.58	....	....	....	....	....	8,671	15,608
Same (face of room 7, off heading 2, 7,000 feet northeast of shaft; 3-foot 10⅝-inch bed, 3-foot 9⅝-inch cut).	261	15055	A	1	1.55	15.86	68.84	13.75	2.04	....	....	....	....	1.2	7,299	13,138
				2	....	16.11	69.92	13.97	2.07	....	....	....	....	....	7,414	13,345
				3	....	18.73	81.27	....	2.41	....	....	....	....	....	8,618	15,512
Same (600 feet to the right from top of plane 3; 5,100 feet northeast of shaft; 4-foot 8¼-inch bed, 4-foot 3¼-inch cut).	261	15056	A	1	1.25	16.58	71.67	10.50	1.00	....	....	....	....	1.0	7,646	13,763
				2	....	16.79	72.58	10.63	1.01	....	....	....	....	....	7,743	13,937
				3	....	18.79	81.21	....	1.13	....	....	....	....	....	8,664	15,595
Same (face of heading 3; 7,400 feet northeast of shaft; 3-foot 11½-inch bed and cut).	261	15058	A	1	1.74	15.88	69.60	12.78	2.42	....	....	....	....	1.4	7,355	13,239
				2	....	16.16	70.83	13.01	2.46	....	....	....	....	....	7,485	13,473
				3	....	18.58	81.42	....	2.83	....	....	....	....	....	8,605	15,489

Same (face of room, 200 feet from face of heading 4, 7,000 feet northeast of shaft, 3-foot 7½-inch bed and cut).	261	15059	A	1	1.61	16.78	69.70	11.91	2.20	....	....	....	....	1.2	7,496	13,493
				2	....	17.06	70.83	12.11	2.24	....	....	....	....	....	7,619	13,714
				3	....	19.41	80.59	....	2.55	....	....	....	....	....	8,669	15,604
Same (composite of samples 15055, 15056, 15058, and 15059).	261	15060	A	1	1.58	16.32	69.98	12.12	1.94	4.09	77.01	1.44	3.40	1.2	7,449	13,408
				2	....	16.58	71.10	12.32	1.97	3.97	78.25	1.46	2.03	....	7,569	13,624
				3	....	18.91	81.09	....	2.25	4.53	89.24	1.67	2.31	....	8,632	15,538
CAMBRIA COUNTY.																
Barnesboro, 1 mile east of; Allport mine, Lower Freeport or D bed (face of left entry 2, off heading 9, off main heading, 6,250 feet southeast of mine mouth, 4-foot 4½-inch bed, 4-foot 1⅞-inch cut).	262	W19740	A	1	3.5	20.9	68.2	7.4	1.80	....	....	....	....	....	7,739	13,930
				2	....	21.7	70.6	7.7	1.85	....	....	....	....	....	8,017	14,430
				3	....	23.5	76.5	....	2.00	....	....	....	....	....	8,683	15,630
Same (rib in room 7, off left entry 2, off right entry 9, off main heading, 6,250 feet southeast of mine mouth, 4-foot 10½-inch bed, 4-foot 9½-inch cut).	262	W19741	A	1	2.9	20.7	68.8	7.6	1.75	....	....	....	....	....	7,806	14,050
				2	....	21.3	70.9	7.8	1.80	....	....	....	....	....	8,039	14,470
				3	....	23.1	76.9	....	1.95	....	....	....	....	....	8,722	15,709
Same (face of right entry 9, off main heading, 6,950 feet southwest of mine mouth, 4-foot 8-inch bed, 4-foot 6½-inch cut).	262	W19742	A	1	2.3	21.9	69.2	6.6	1.40	....	....	....	....	....	7,933	14,280
				2	....	22.4	70.8	6.8	1.45	....	....	....	....	....	8,117	14,610
				3	....	24.0	76.0	....	1.56	....	....	....	....	....	8,706	15,670
Same (composite of samples W19740, W19741, and W19742).	262	12221	A	1	1.75	21.70	69.13	7.42	1.81	4.69	80.33	1.38	4.37	....	7,904	14,227
				2	....	22.09	70.36	7.55	1.84	4.58	81.76	1.40	2.87	....	8,045	14,481
				3	....	23.89	76.11	....	1.99	4.95	88.44	1.51	3.11	....	8,702	15,664
1 mile east of; Allport mine, Upper Freeport or E bed (face of right entry 3, off main heading, 3,700 feet southeast of mine mouth, 3-foot 8⅝-inch bed, 3-foot 6-inch cut).	262	W19738	A	1	2.3	22.2	67.6	7.9	1.05	....	....	....	....	....	7,822	14,080
				2	....	22.7	69.2	8.1	1.10	....	....	....	....	....	8,011	14,420
				3	....	24.7	75.3	....	1.20	....	....	....	....	....	8,717	15,690
Same (face of main slant, off main entry, 3,700 feet southeast of mine mouth, 3-foot 7-inch bed, 3-foot 5-inch cut).	262	W19739	A	1	2.4	22.7	67.4	7.5	.80	....	....	....	....	....	7,883	14,190
				2	....	23.3	69.0	7.7	.80	....	....	....	....	....	8,072	14,530
				3	....	25.2	74.8	....	.87	....	....	....	....	....	8,744	15,740
Same (600 feet in on second panel from main slant, off main entry, 2,800 feet south of mine mouth, 3-foot 7½-inch bed and cut).	262	W19743	A	1	2.5	23.2	68.4	5.9	.65	....	....	....	....	....	7,989	14,380
				2	....	23.8	70.1	6.1	.70	....	....	....	....	....	8,189	14,740
				3	....	25.3	74.7	....	.75	....	....	....	....	....	8,717	15,690
Same (composite of samples W19738, W19739, and W19743).	262	12231	A	1	1.45	23.40	67.92	7.23	.83	4.78	81.06	1.35	4.75	....	7,934	14,281
				2	....	23.74	68.92	7.34	.84	4.69	82.25	1.37	3.51	....	8,051	14,492
				3	....	25.62	74.38	....	.91	5.06	88.76	1.48	3.79	....	8,689	15,640
1¾ miles east of; Cymbria mine, Miller, B, or Lower Kittanning bed (face of right entry 2, about 1,000 feet southwest of shaft, 2-foot 10½-inch bed, 2-foot 9¾-inch cut).	263	W20394	A	1	2.2	20.4	71.5	5.9	.85	....	....	....	....	....	8,022	14,440
				2	....	20.9	73.1	6.0	.85	....	....	....	....	....	8,206	14,770
				3	....	22.2	77.8	....	.90	....	....	....	....	....	8,728	15,710
Same (face of room 18, off left entry 2, 1,200 feet northeast of shaft, 2-foot 7¼-inch bed and cut).	263	W20395	A	1	2.1	21.7	70.8	5.4	.85	....	....	....	....	....	8,094	14,570
				2	....	22.2	72.3	5.5	.85	....	....	....	....	....	8,272	14,890
				3	....	23.5	76.5	....	.90	....	....	....	....	....	8,756	15,760
Same (face of main heading, 1,900 feet from shaft, 2-foot 4⅜-inch bed, 2-foot 4¼-inch cut).	263	W20444	A	1	2.3	21.4	67.4	8.9	3.00	....	....	....	....	....	7,728	13,910
				2	....	21.9	69.0	9.1	3.10	....	....	....	....	....	7,911	14,240
				3	....	24.1	75.9	....	3.41	....	....	....	....	....	8,706	15,670
Same (face of left entry 3, 1,400 feet northeast of shaft, 2-foot 5-inch bed and cut).	263	W20445	A	1	3.1	21.3	67.1	8.5	3.15	....	....	....	....	....	7,694	13,850
				2	....	22.0	69.2	8.8	3.30	....	....	....	....	....	7,939	14,290
				3	....	24.1	75.9	....	3.62	....	....	....	....	....	8,700	15,660
Same (face of right entry 3, 1,200 feet southeast of shaft, 2-foot 11-inch bed and cut).	263	W20446	A	1	3.4	22.1	68.3	6.2	1.20	....	....	....	....	....	7,944	14,300
				2	....	22.9	70.7	6.4	1.25	....	....	....	....	....	8,228	14,810
				3	....	24.5	75.5	....	1.34	....	....	....	....	....	8,794	15,830
Same (composite of samples W20394, W20395, W20444, W20445, and W20446).	263	12372	A	1	.82	22.86	69.15	7.17	2.02	4.66	81.56	1.23	3.36	....	8,024	14,443
				2	....	23.05	69.72	7.23	2.04	4.61	82.24	1.24	2.64	....	8,091	14,564
				3	....	24.85	75.15	....	2.20	4.97	88.65	1.34	2.84	....	8,721	15,698

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CAMBRIA COUNTY—continued.																
Barnesboro, 2 miles east of; Cymbria No. 1 mine, Lower Freeport or D bed (face of first crosscut, off left entry 2, 5,500 feet from mine mouth, 4-foot 5-inch bed, 4-foot 1-inch cut).	264	12162	A	1	3.42	22.74	66.91	6.93	1.77	......	......	......	......	2.8	7,801	14,042
				2	......	23.54	69.28	7.18	1.83	......	......	......	......	......	8,077	14,539
				3	......	25.36	74.64	......	1.97	......	......	......	......	......	8,702	15,664
Same (face of eighth right, off left entry 2, 4,000 feet from mine mouth, 3-foot 11½-inch bed, 3-foot 6½-inch cut).	264	12163	A	1	2.57	23.10	67.49	6.84	1.22	......	......	......	......	2.0	7,891	14,204
				2	......	23.71	69.27	7.02	1.25	......	......	......	......	......	8,099	14,578
				3	......	25.50	74.50	......	1.34	......	......	......	......	......	8,710	15,678
Same (face of first left, off left entry 2, 4,000 feet from mine mouth, 4-foot 7½-inch bed, 4-foot 3¾-inch cut).	264	12164	A	1	2.95	23.41	67.74	5.90	1.34	......	......	......	......	2.4	7,940	14,292
				2	......	24.12	69.80	6.08	1.38	......	......	......	......	......	8,181	14,726
				3	......	25.68	74.32	......	1.47	......	......	......	......	......	8,710	15,678
Same (face of third right, off main entry 2, 3,200 feet northeast of mine mouth, 4-foot 1¾-inch bed, 3-foot 10½-inch cut).	264	12170	A	1	2.76	22.69	68.08	6.47	1.57	......	......	......	......	2.2	7,882	14,188
				2	......	23.33	70.02	6.65	1.61	......	......	......	......	......	8,106	14,591
				3	......	24.99	75.01	......	1.72	......	......	......	......	......	8,683	15,629
Same (face of second left, off main heading, 2,900 feet northeast of mine mouth, 4-foot 3½-inch bed, 4-foot ¾-inch cut).	264	12171	A	1	2.98	23.46	67.84	5.72	1.41	......	......	......	......	2.4	7,963	14,333
				2	......	24.18	69.92	5.90	1.45	......	......	......	......	......	8,207	14,773
				3	......	25.70	74.30	......	1.54	......	......	......	......	......	8,722	15,700
Same (composite of samples 12162, 12163, 12164, 12170, and 12171).	264	12165	A	1	3.08	22.50	67.93	6.49	1.59	5.01	80.39	1.26	5.26	2.4	7,875	14,175
				2	......	23.22	70.08	6.70	1.64	4.82	82.95	1.30	2.59	......	8,125	14,625
				3	......	24.89	75.11	......	1.76	5.17	88.91	1.39	2.77	......	8,708	15,674
2 miles east of; Cymbria No. 2½ mine, Upper Freeport or E bed (face of left entry 2, 2,000 feet from mine mouth, 3-foot 7¾-inch bed, 3-foot 4¾-inch cut).	265	12158	A	1	2.76	24.03	63.89	9.32	1.52	......	......	......	......	2.2	7,647	13,765
				2	......	24.71	65.71	9.58	1.56	......	......	......	......	......	7,864	14,155
				3	......	27.33	72.67	......	1.73	......	......	......	......	......	8,697	15,655
Same (face of room 12, off main heading, 2,200 feet from mine mouth, 3-foot 7½-inch bed, 3-foot 5-inch cut).	265	12159	A	1	3.24	23.16	65.86	7.74	1.38	......	......	......	......	2.6	7,773	13,991
				2	......	23.94	68.06	8.00	1.43	......	......	......	......	......	8,033	14,459
				3	......	26.02	73.98	......	1.55	......	......	......	......	......	8,732	15,718
Same (face of third left main heading, 3-foot 7¾-inch bed, 3-foot 4¾-inch cut).	265	12160	A	1	3.88	22.74	65.76	7.62	1.37	......	......	......	......	3.2	7,720	13,896
				2	......	23.66	68.41	7.93	1.43	......	......	......	......	......	8,032	14,458
				3	......	25.70	74.30	......	1.55	......	......	......	......	......	8,724	15,703

Same (face of room 6, off main heading, 1,500 feet southwest of mine mouth, 3-foot 7¾-inch bed, 3-foot 4¼-inch cut).	265	12172	A	1	2.88	23.22	65.74	8.16	1.67	....	....	....	....	2.3	7,745	13,941
				2	....	23.91	67.69	8.40	1.72	....	....	....	....	....	7,975	14,355
				3	....	26.10	73.90	....	1.88	....	....	....	....	....	8,706	15,671
Same (face of room 8, off left heading 2, 1,200 feet southwest of mine mouth, 3-foot 9¼-inch bed, 3-foot 8-inch cut).	265	12173	A	1	2.97	22.98	65.43	8.62	1.98	....	....	....	....	2.4	7,688	13,838
				2	....	23.68	67.44	8.88	2.04	....	....	....	....	....	7,923	14,261
				3	....	25.99	74.01	....	2.24	....	....	....	....	....	8,695	15,651
Same (composite of samples 12158, 12159, 12160, 12172, and 12173).	265	12161	A	1	2.98	22.85	65.78	8.39	1.63	5.02	77.87	1.32	5.77	2.5	7,726	13,907
				2	....	23.55	67.80	8.65	1.68	4.84	80.26	1.36	3.21	....	7,963	14,333
				3	....	25.78	74.22	....	1.84	5.30	87.86	1.49	3.51	....	8,717	15,691
¾ mile west of; Empire A mine, Lower Freeport or D bed (room 1, off left entry 5, off new parallel heading, 14,000 feet northwest of drift mouth, 4-foot 4¾-inch bed, 4-foot ½-inch cut).	265	W19643	A	1	2.6	23.3	66.9	7.2	1.25	....	....	....	....	....	7,817	14,070
				2	....	23.9	68.7	7.4	1.30	....	....	....	....	....	8,022	14,440
				3	....	25.8	74.2	....	1.40	....	....	....	....	....	8,667	15,600
Same (face of room 4, off old first left heading, off main entry, 2,000 feet northwest of drift mouth, 4-foot 6¾-inch bed, 4-foot 3-inch cut).	265	W19644	A	1	1.9	23.8	67.6	6.7	1.05	....	....	....	....	....	7,956	14,320
				2	....	24.3	68.9	6.8	1.10	....	....	....	....	....	8,111	14,600
				3	....	26.1	73.9	....	1.18	....	....	....	....	....	8,700	15,660
Same (corner of back heading, off right entry 3, off old parallel heading, 3,000 feet northeast of drift mouth, 4-foot 4¼-inch bed, 4-foot 2¼-inch cut).	265	W19645	A	1	2.3	23.1	67.5	7.1	1.15	....	....	....	....	....	7,828	14,090
				2	....	23.7	69.0	7.3	1.20	....	....	....	....	....	8,017	14,430
				3	....	25.6	74.4	....	1.29	....	....	....	....	....	8,650	15,570
Same (40 feet from face of parallel heading, off main entry, 9,000 feet northeast of drift mouth, 4-foot 3¾-inch bed, 4-foot ½-inch cut).	265	W19646	A	1	3.3	24.5	65.0	7.2	1.85	....	....	....	....	....	7,778	14,000
				2	....	25.3	67.3	7.4	1.90	....	....	....	....	....	8,044	14,480
				3	....	27.3	72.7	....	2.05	....	....	....	....	....	8,689	15,640
Same (face of room 24, off left entry 14, off main entry, 11,000 feet northwest of drift mouth, 3-foot 9¼-inch bed, 3-foot 6⅝-inch cut).	265	W19647	A	1	2.1	22.7	66.5	8.7	1.80	....	....	....	....	....	7,728	13,910
				2	....	23.2	67.9	8.9	1.85	....	....	....	....	....	7,894	14,210
				3	....	25.5	74.5	....	2.03	....	....	....	....	....	8,667	15,600
Same (face of room 17, off left entry 3, off new parallel heading, 14,000 feet northwest of drift mouth, 4-foot 10½-inch bed, 4-foot 6½-inch cut).	265	W19648	A	1	2.4	23.5	67.2	6.9	1.50	....	....	....	....	....	7,883	14,190
				2	....	24.1	68.8	7.1	1.55	....	....	....	....	....	8,078	14,540
				3	....	25.9	74.1	....	1.67	....	....	....	....	....	8,694	15,650
Same (composite of W19643, W19644, W19645, W19646, W19647, and W19648).	265	12212	A	1	1.54	23.86	67.08	7.52	1.53	4.73	80.47	1.38	4.37	....	7,886	14,195
				2	....	24.23	68.13	7.64	1.55	4.63	81.73	1.40	3.05	....	8,009	14,416
				3	....	26.23	73.77	....	1.68	5.01	88.49	1.52	3.30	....	8,671	15,608
Beaverdale; Pennsylvania No. 15 mine, Kittanning or B bed (face of first slant, off right heading 5, off first dip, off main entry, 3-foot 3-inch bed and cut).	266	12174	A	1	3.25	15.85	73.42	7.48	2.10	....	....	....	....	2.8	7,807	14,053
				2	....	16.38	75.89	7.73	2.17	....	....	....	....	....	8,069	14,524
				3	....	17.75	82.25	....	2.35	....	....	....	....	....	8,745	15,741
Same (face of sump for main dip, off left heading 4, off first dip, off main entry, 3-foot 4¼-inch bed and cut).	266	12175	A	1	2.72	16.70	75.38	5.20	.55	....	....	....	....	2.2	8,067	14,521
				2	....	17.17	77.48	5.35	.57	....	....	....	....	....	8,293	14,927
				3	....	18.14	81.86	....	.60	....	....	....	....	....	8,762	15,772
Same (face of first slant, off right heading 4, off first dip off main entry, 3-foot 4-inch bed and cut).	266	12176	A	1	3.90	15.09	73.03	7.98	2.28	....	....	....	....	3.3	7,720	13,896
				2	....	15.70	76.00	8.30	2.37	....	....	....	....	....	8,033	14,459
				3	....	17.12	82.88	....	2.58	....	....	....	....	....	8,760	15,768
Same (face of first slant, off right heading 3, off first dip off main entry, 3-foot 1-inch bed and cut).	266	12177	A	1	3.53	15.68	73.95	6.84	1.94	....	....	....	....	3.0	7,847	14,125
				2	....	16.25	76.66	7.09	2.01	....	....	....	....	....	8,134	14,641
				3	....	17.49	82.51	....	2.16	....	....	....	....	....	8,755	15,759
Same (composite of samples 12174, 12175, 12176, and 12177).	266	12178	A	1	3.44	16.18	73.46	6.92	1.83	4.64	80.61	1.20	4.80	2.8	7,841	14,114
				2	....	16.76	76.07	7.17	1.90	4.41	83.48	1.24	1.80	....	8,120	14,616
				3	....	18.05	81.95	....	2.05	4.75	89.92	1.34	1.94	....	8,747	15,745
Same (pillar, room 23, off right heading 3, off first dip, off main entry).	266	12179	A	1	2.89	14.68	74.83	7.60	2.36	4.59	80.18	1.25	4.02	2.4	7,817	14,071
				2	....	15.12	77.05	7.83	2.43	4.40	82.57	1.29	1.48	....	8,050	14,490
				3	....	16.41	83.59	....	2.64	4.77	89.59	1.40	1.60	....	8,734	15,721

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CAMBRIA COUNTY—continued.																
Bens Creek, 1 mile east of; Bens Creek No. 1 mine, Miller, B, or Lower Kittanning bed (barrier pillar on No. 2 side track, 100 feet from room 21 and 3,200 feet southwest of old main heading, 3-foot 6¾-inch bed and cut).	267	W19697	A	1	2.1	17.0	74.7	6.2	1.10	......	......	......	......	......	8,017	14,430
				2	......	17.4	76.3	6.3	1.15	......	......	......	......	......	8,189	14,740
				3	......	18.6	81.4	......	1.23	......	......	......	......	......	8,739	15,730
Same (pillar on No. 1 side track, between manway and room 1, 1,200 feet southwest of shaft, 3-foot 1½-inch bed and cut).	267	W19700	A	1	3.4	16.3	74.7	5.6	.55	......	......	......	......	......	7,956	14,320
				2	......	16.9	77.3	5.8	.60	......	......	......	......	......	8,233	14,820
				3	......	17.9	82.1	......	.64	......	......	......	......	......	8,739	15,730
Same (main pillar of old main heading, 900 feet southwest of shaft, 3-foot 9-inch bed and cut).	267	W19702	A	1	3.7	17.7	72.7	5.9	.65	......	......	......	......	......	7,933	14,280
				2	......	18.3	75.6	6.1	.70	......	......	......	......	......	8,233	14,820
				3	......	19.5	80.5	......	.75	......	......	......	......	......	8,772	15,790
Same (pillar of heading 1, between rooms 27 and 28, 2,700 feet southwest of shaft, 3-foot 7¾-inch bed and cut).	267	W19737	A	1	3.3	16.3	74.7	5.7	1.05	......	......	......	......	......	8,000	14,400
				2	......	16.9	77.2	5.9	1.10	......	......	......	......	......	8,272	14,890
				3	......	18.0	82.0	......	1.17	......	......	......	......	......	8,789	15,820
Same (composite of samples W19697, W19700, W19702, and W19737).	267	12211	A	1	1.83	16.82	75.34	6.01	.84	4.56	83.43	1.28	3.88	......	8,080	14,544
				2	......	17.13	76.75	6.12	.86	4.44	84.98	1.30	2.30	......	8,230	14,814
				3	......	18.25	81.75	......	.92	4.73	90.52	1.38	2.45	......	8,767	15,781
Same (face of heading 6, off first dip, 700 feet southeast of shaft, 3-foot 4-inch bed and cut).	267	W19736	A	1	2.6	16.6	74.8	6.0	.75	......	......	......	......	......	8,028	14,450
				2	......	17.0	76.8	6.2	.80	......	......	......	......	......	8,239	14,830
				3	......	18.1	81.9	......	.85	......	......	......	......	......	8,783	15,810
1 mile south of; Pennsylvania No. 2 mine, Miller, B, or Lower Kittanning bed (face of heading 19, 4,100 feet northeast of drift mouth, 3-foot 9¼-inch bed, 3-foot 7½-inch cut).	268	W19695	A	1	2.8	16.2	74.0	7.0	1.50	......	......	......	......	......	7,961	14,330
				2	......	16.7	76.1	7.2	1.55	......	......	......	......	......	8,189	14,740
				3	......	18.0	82.0	......	1.67	......	......	......	......	......	8,822	15,880
Same (pillar between rooms 14 and 15, fourth main heading, 2,900 feet northwest of drift mouth, 3-foot 3¾-inch bed, 3-foot 3¾-inch cut).	268	W19695	A	1	2.4	16.6	74.3	6.7	1.10	......	......	......	......	......	7,978	14,360
				2	......	17.0	76.1	6.9	1.15	......	......	......	......	......	8,178	14,720
				3	......	18.3	81.7	......	1.24	......	......	......	......	......	8,783	15,810
Same (pillar between rooms 2 and 3, off butt entry 17, 3,900 feet north of drift mouth, 3-foot 7¾-inch bed and cut).	268	W19698	A	1	2.8	16.4	75.6	5.2	.90	......	......	......	......	......	8,083	14,550
				2	......	16.9	77.8	5.3	.95	......	......	......	......	......	8,317	14,970
				3	......	17.8	82.2	......	1.00	......	......	......	......	......	8,783	15,810

Same (pillar between rooms 1 and 2, off butt entry 16, 3,900 feet north of drift mouth, 3-foot 5-inch bed and cut).	268	W19699	A	1	2.7	16.2	75.8	5.3	.75	......	......	......	......	......	8,078	14,540
				2	......	16.7	77.9	5.4	.80	......	......	......	......	......	8,300	14,940
				3	......	17.7	82.8	......	.85	......	......	......	......	......	8,778	15,800
Same (pillar between rooms 21 and 22, off heading 5, 3,200 feet north of drift mouth, 3-foot 6¼-inch bed and cut).	268	W19701	A	1	2.3	16.8	74.7	6.2	1.30	......	......	......	......	......	8,083	14,550
				2	......	17.2	76.5	6.3	1.35	......	......	......	......	......	8,272	14,890
				3	......	18.4	81.6	......	1.44	......	......	......	......	......	8,828	15,890
Same (composite of samples W19695, W19696, W19698, W19699, and W19701).	268	12222	A	1	1.57	16.13	76.31	5.99	1.09	4.56	83.76	1.32	3.28	......	8,106	14,591
				2	......	16.39	77.52	6.09	1.11	4.46	85.09	1.34	1.91	......	8,235	14,823
				3	......	17.45	82.55	......	1.18	4.75	90.60	1.43	2.04	......	8,769	15,784
Carroltown Road, ½ mile west of; Logan No. 5 mine, Miller bed (in first main heading, 4,300 feet south of mine mouth, 2-foot 6½-inch bed and cut).	269	W20364	A	1	2.2	19.8	71.7	6.3	1.00	......	......	......	......	......	7,972	14,350
				2	......	20.2	73.4	6.4	1.05	......	......	......	......	......	8,150	14,670
				3	......	21.6	78.4	......	1.12	......	......	......	......	......	8,706	15,670
Same (face of right entry 2; 250 feet from second main heading and 3,750 feet south of mine mouth, 2-foot 5$\frac{3}{16}$-inch bed and cut).	269	W20365	A	1	2.2	22.4	68.6	6.8	1.20	......	......	......	......	......	7,922	14,260
				2	......	22.9	70.1	7.0	1.25	......	......	......	......	......	8,100	14,580
				3	......	24.6	75.4	......	1.34	......	......	......	......	......	8,706	15,670
Same (face of room 8, off air course of right entry 1, off second main entry, 4,300 feet south of mine mouth, 2-foot 6½-inch bed and cut).	269	W20366	A	1	1.6	22.7	68.6	7.1	1.15	......	......	......	......	......	7,939	14,290
				2	......	23.1	69.7	7.2	1.20	......	......	......	......	......	8,072	14,530
				3	......	24.9	75.1	......	1.29	......	......	......	......	......	8,700	15,660
Same (face of second main heading, 3,600 feet southeast of mine mouth, 2-foot 4½-inch bed and cut).	269	W20367	A	1	2.2	23.0	67.8	7.0	1.35	......	......	......	......	......	7,989	14,380
				2	......	23.5	69.4	7.1	1.40	......	......	......	......	......	8,167	14,700
				3	......	25.3	74.7	......	1.51	......	......	......	......	......	8,789	15,820
Same (face of fourth left heading, off second main heading, 3,200 feet southeast of mine mouth, 2-foot 6¼-inch bed and cut).	269	W20368	A	1	2.0	22.4	70.0	5.6	1.30	......	......	......	......	......	8,078	14,540
				2	......	22.9	71.4	5.7	1.35	......	......	......	......	......	8,244	14,840
				3	......	24.3	75.7	......	1.43	......	......	......	......	......	8,744	15,740
Same (composite of samples W20364–W20368).....	269	12370	A	1	.93	23.10	69.29	6.68	1.30	4.81	81.64	1.26	4.31	......	8,047	14,485
				2	......	23.32	69.94	6.74	1.31	4.75	82.41	1.27	3.52	......	8,123	14,621
				3	......	25.01	74.99	......	1.40	5.09	88.37	1.36	3.78	......	8,710	15,678
Colver; Colver mine, B bed (face of main entry A, 2,400 feet southwest of bore hole, 3-foot 11-inch bed, 3-foot 7¾-inch cut).	269	13634	A	1	[a] 2.24	22.04	69.08	6.64	1.76	......	......	......	......	1.1	8,001	14,402
				2	......	22.54	70.67	6.79	1.80	......	......	......	......	......	8,184	14,731
				3	......	24.18	75.82	......	1.93	......	......	......	......	......	8,780	15,804
Same (face of entry A–2, 1,175 feet southeast of bore hole 25, 4-foot 1¼-inch bed, 3-foot 10-inch cut).	269	13635	A	1	[a] 1.96	20.77	71.28	5.99	1.01	......	......	......	......	.7	8,065	14,517
				2	......	21.19	72.70	6.11	1.03	......	......	......	......	......	8,226	14,807
				3	......	22.57	77.43	......	1.10	......	......	......	......	......	8,762	15,772
Same (face of entry A–3, 1,400 feet south of bore hole 25, 4-foot 2-inch bed, 3-foot 10¼-inch cut).	269	13636	A	1	[a] 2.02	21.85	68.85	7.28	1.42	......	......	......	......	.8	7,937	14,287
				2	......	22.30	70.27	7.43	1.45	......	......	......	......	......	8,101	14,582
				3	......	24.09	75.91	......	1.57	......	......	......	......	......	8,752	15,754
Same (face of main heading, 1,200 feet southeast of bore hole 25, 4-foot 3-inch bed, 3-foot 10-inch cut).	269	13637	A	1	[a] 2.77	20.58	71.74	4.91	.92	......	......	......	......	1.1	8,104	14,587
				2	......	21.17	73.78	5.05	.95	......	......	......	......	......	8,335	15,003
				3	......	22.30	77.70	......	1.00	......	......	......	......	......	8,778	15,800
Same (face of entry B–1, 725 feet southeast of bore hole 25, 3-foot 10-inch bed, 3-foot 6-inch cut).	269	13638	A	1	[a] 2.16	20.66	72.04	5.14	.97	......	......	......	......	.9	8,126	14,627
				2	......	21.12	73.63	5.25	.99	......	......	......	......	......	8,306	14,951
				3	......	22.29	77.71	......	1.04	......	......	......	......	......	8,766	15,779
Same (face of entry A–1, 950 feet southeast of bore hole 25, 4-foot 1-inch bed, 3-foot 7¾-inch cut).	269	13639	A	1	[a] 1.89	20.92	71.82	5.37	.95	......	......	......	......	.7	8,120	14,616
				2	......	21.32	73.21	5.47	.97	......	......	......	......	......	8,277	14,899
				3	......	22.55	77.45	......	1.03	......	......	......	......	......	8,756	15,761
Same (composite of samples 13634–13639)..........	270	13640	A	1	2.00	21.17	70.90	5.93	1.23	4.64	81.57	1.57	5.06	.9	8,062	14,512
				2	......	21.60	72.35	6.05	1.26	4.51	83.23	1.60	3.35	......	8,226	14,807
				3	......	22.99	77.01	......	1.34	4.80	88.59	1.70	3.57	......	8,756	15,761

[a] Sample air dried a few hours only, does not represent the total moisture as received.

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CAMBRIA COUNTY—continued.																
Colver; Colver mine, B bed (position, bed, and cut same as sample 13639).	269	13641	A	1	[a] 1.93	20.93	71.91	5.23	1.02					1.5		
				2		21.34	73.33	5.33	1.04							
				3		22.54	77.46		1.10							
Same (position, bed, and cut same as sample 13638).	269	13642	A	1	[a] 3.27	20.04	71.50	5.19	1.05					2.8		
				2		20.72	73.91	5.37	1.09							
				3		21.89	78.11		1.15							
Same (position, bed, and cut same as sample 13637).	269	13643	A	1	[a] 4.66	19.73	70.91	4.70	.88					4.2		
				2		20.69	74.38	4.93	.92							
				3		21.76	78.24		.97							
Dunlo, one mile south of; Henriette mine, Miller or B bed (rib of room 2, off right heading 1, off slope 2,700 feet north of shaft No. 2, 3-foot 9½-inch bed, 3-foot 5½-inch cut).	270	14238	A	1	2.34	18.70	74.24	4.72	.60					1.3		
				2		19.15	76.02	4.83	.61							
				3		20.12	79.88		.64							
Same (junction of sixth slant and main heading, on curve, 3,050 feet north of shaft No. 2, 3-foot 10-inch bed, 3-foot 7-inch cut).	270	14239	A	1	2.56	18.57	73.86	5.01	.75					1.4		
				2		19.06	75.80	5.14	.77							
				3		20.09	79.91		.81							
Same (rib of pillar of left entry 6, near room 13, north of rock fault, 4,350 feet northwest of shaft No. 2, 3-foot 6½-inch bed, 3-foot 4½-inch cut).	270	14240	A	1	3.01	17.45	74.94	4.60	.60					1.9		
				2		17.99	77.27	4.74	.62							
				3		18.89	81.11		.65							
Same (pillar of left heading 6, 450 feet north of back heading off slope 2, 4,150 feet northwest of shaft No. 2, 3-foot 7½-inch bed, 3-foot 4-inch cut).	270	14241	A	1	2.77	17.41	75.19	4.63	.68					1.8		
				2		17.91	77.33	4.76	.70							
				3		18.81	81.19		.74							
Same (rib between rooms 1 and 2, first level above main entry, about 1,500 feet northwest of shaft No. 2, 3-foot 8-inch cut).	270	14242	A	1	2.82	18.42	74.25	4.51	.59					1.8		
				2		18.95	76.41	4.64	.61							
				3		19.87	80.13		.64							
Same (composite of samples 14238-14242)	271	14243	A	1	2.65	18.08	74.64	4.63	.62	4.55	83.80	1.35	5.05	1.6	8,089	14,560
				2		18.57	76.67	4.76	.64	4.38	86.08	1.39	2.75		8,309	14,956
				3		19.50	80.50		.67	4.60	90.38	1.46	2.89		8,724	15,703
Same (position and bed same as sample 14240, 2 inches of top coal or bone).	270	14244	A	1	2.84	17.66	75.19	4.91	.53					1.7		
				2		17.56	77.39	5.05	.55							
				3		18.49	81.51		.58							

Same (position and bed same as sample 14238, 4 inches of top coal or bone).	270	14245	A	1	2.39	19.11	74.89	3.61	.55	......	......	......	......	1.5	......	......
				2	......	19.58	76.72	3.70	.56	......	......	......	......	......	......	......
				3	......	20.33	79.67	......	.58	......	......	......	......	......	......	......
Same (position and bed same as sample 14239, 3 inches of top coal or bone).	270	14246	A	1	1.80	18.60	69.71	9.89	2.07	......	......	......	......	.8	......	......
				2	......	18.94	70.99	10.07	2.11	......	......	......	......	......	......	......
				3	......	21.06	78.94	......	2.35	......	......	......	......	......	......	......
El Mora, near; Peerless No. 1 mine, Lower Kittanning or B bed (heading stump on left entry 3, off main entry, about 1,700 feet northeast of drift mouth, 3-foot 3¾-inch bed and cut).	271	12134	A	1	3.18	20.91	69.73	6.18	1.97	......	......	......	......	2.6	7,939	14,290
				2	......	21.60	72.02	6.38	2.03	......	......	......	......	......	8,199	14,758
				3	......	23.07	76.93	......	2.17	......	......	......	......	......	8,757	15,763
Same (face of room 1, right heading 8, off main entry, 2,300 feet east of drift mouth, 3-foot ½-inch bed and cut).	271	12135	A	1	3.55	21.42	68.06	6.97	1.31	......	......	......	......	2.9	7,840	14,112
				2	......	22.21	70.56	7.23	1.36	......	......	......	......	......	8,129	14,632
				3	......	23.94	76.06	......	1.47	......	......	......	......	......	8,762	15,772
Same (face of left heading 7, off main entry, about 2,800 feet northeast of drift mouth, 2-foot 11½-inch bed, 2-foot 11-inch cut).	271	12136	A	1	3.28	21.07	69.19	6.46	1.43	......	......	......	......	2.5	7,953	14,315
				2	......	21.78	71.54	6.68	1.48	......	......	......	......	......	8,223	14,801
				3	......	23.34	76.66	......	1.59	......	......	......	......	......	8,812	15,862
Same (rib of room 1, right heading 3, off main heading, 1,600 feet southeast of drift mouth, 2-foot 11¾-inch bed and cut).	271	12137	A	1	3.59	20.43	68.79	7.19	1.95	......	......	......	......	2.7	7,875	14,175
				2	......	21.19	71.35	7.46	2.02	......	......	......	......	......	8,168	14,702
				3	......	22.90	77.10	......	2.18	......	......	......	......	......	8,826	15,887
Same (425 feet in heading 1, off main entry, 2-foot 11¼-inch bed and cut).	271	12138	A	1	3.92	20.85	69.19	6.04	.90	......	......	......	......	3.3	7,809	14,056
				2	......	21.70	72.01	6.29	.94	......	......	......	......	......	8,128	14,630
				3	......	23.16	76.84	......	1.00	......	......	......	......	......	8,673	15,611
Same (composite of samples 12134–12138).........	272	12139	A	1	3.47	20.73	69.39	6.41	1.55	4.88	80.02	1.36	5.78	2.8	7,874	14,173
				2	......	21.47	71.89	6.64	1.61	4.65	82.89	1.41	2.80	......	8,157	14,683
				3	......	23.00	77.00	......	1.72	4.98	88.78	1.51	3.01	......	8,737	15,727
Figart, 1¼ miles northeast of; Frick No. 2 mine, Middle Kittanning or C bed (face of main heading 2, 400 feet from mouth of main entry, 3-foot 2¼-inch bed, 2-foot 2¾-inch cut).	272	W20433	A	1	2.2	24.6	64.2	9.0	1.15	......	......	......	......	......	7,694	13,850
				2	......	25.1	65.7	9.2	1.20	......	......	......	......	......	7,867	14,160
				3	......	27.6	72.4	......	1.32	......	......	......	......	......	8,667	15,600
Same (face of entry 1, off second main heading, 400 feet from mouth of main entry, 3-foot 1-inch bed, 2-foot 3½-inch cut).	272	W20434	A	1	2.4	23.2	64.5	9.9	1.35	......	......	......	......	......	7,617	13,710
				2	......	23.8	66.1	10.1	1.40	......	......	......	......	......	7,800	14,040
				3	......	26.5	73.5	......	1.56	......	......	......	......	......	8,672	15,610
Same (face of room 5, off main left heading, 850 feet from mouth of main entry, 3-foot 2¼-inch bed, 2-foot ¾-inch cut).	272	W20474	A	1	2.6	24.1	66.6	6.7	1.00	......	......	......	......	......	7,861	14,150
				2	......	24.8	68.3	6.9	1.05	......	......	......	......	......	8,072	14,530
				3	......	26.6	73.4	......	1.13	......	......	......	......	......	8,667	15,600
Same (face of first left heading, 500 feet from mouth of main entry, 3-foot 1-inch bed, 2-foot 4-inch cut).	272	W20475	A	1	2.9	23.4	65.2	8.5	.95	......	......	......	......	......	7,694	13,850
				2	......	24.1	67.1	8.8	1.00	......	......	......	......	......	7,928	14,270
				3	......	26.4	73.6	......	1.10	......	......	......	......	......	8,694	15,650
Same (face of straight main heading, 1,200 feet from mouth of entry, 2-foot 11½-inch bed, 1-foot 11½-inch cut).	272	W20476	A	1	2.6	23.9	67.3	6.2	.85	......	......	......	......	......	7,917	14,250
				2	......	24.5	69.1	6.4	.85	......	......	......	......	......	8,133	14,640
				3	......	26.2	73.8	......	.91	......	......	......	......	......	8,689	15,640
Same (composite of samples W20433, W20434, W20474, W20475, and W20476).	272	12366	A	1	1.11	25.68	64.99	8.22	1.18	4.73	79.71	1.26	4.90	......	7,818	14.072
				2	......	25.97	65.72	8.31	1.19	4.66	80.60	1.27	3.97	......	7,906	14,231
				3	......	28.32	71.68	......	1.30	5.08	87.90	1.39	4.33	......	8,622	15,520

[a] Sample air dried the usual length o time, represents true moisture as received.

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CAMBRIA COUNTY—continued.																
Hastings, 2½ miles northeast of; Miller Run mine, Miller or B bed (face of main air course, 2,000 feet from mine mouth, 4-foot 1-inch bed, 3-foot 3-inch cut).	273	W20440	A	1	3.0	22.4	66.3	8.3	1.40						7,694	13,850
				2		23.1	68.3	8.6	1.45						7,933	14,280
				3		25.3	74.7		1.59						8,683	15,630
Same (face of room 4, off right entry 5; 200 feet from main entry), 4-foot 1½-inch bed, 3-foot 3½-inch cut).	273	W20441	A	1	2.1	21.9	66.5	9.5	1.75						7,644	13,760
				2		22.4	67.9	9.7	1.80						7,811	14,060
				3		24.8	75.2		1.99						8,650	15,570
Same (face of right entry 1; 200 feet off left entry 2, 4-foot 1-inch bed, 2-foot 8½-inch cut).	273	W20442	A	1	2.3	22.4	67.0	8.3	.85						7,806	14,050
				2		22.9	68.6	8.5	.90						7,989	14,380
				3		25.0	75.0		.98						8,733	15,720
Same (face of left entry 2; 500 feet off main entry, 4-foot 1⅝-inch bed, 3-foot 4⅝-bed cut).	273	W20443	A	1	2.1	23.5	64.7	9.7	1.25						7,644	13,760
				2		24.0	66.1	9.9	1.30						7,811	14,060
				3		26.6	73.4		1.44						8,667	15,600
Same (composite of sample W20440-W20443).....	273	12371	A	1	.81	23.92	66.15	9.12	1.36	4.67	79.15	1.26	4.44		7,800	14,040
				2		24.12	66.69	9.19	1.37	4.62	79.80	1.27	3.75		7,864	14,155
				3		26.56	73.44		1.51	5.09	87.88	1.40	4.12		8,660	15,588
Same (pillar of room 5, left entry 1; 300 feet off main entry, 3-foot 11½-inch bed, 3-foot 3½-inch cut).	273	W20447	A	1	2.4	21.0	69.9	6.7	.85						7,906	14,230
				2		21.5	71.6	6.9	.90						8,094	14,570
				3		23.1	76.9		.97						8,694	15,650
1 mile south of; Pennsylvania No. 11 mine, Lower Freeport or D bed (face of right entry 5, off main heading, 5-foot 3⅝-inch bed, 4-foot 10¾-inch cut).	274	12150	A	1	2.78	23.49	67.61	6.12	1.16					2.2	7,945	14,301
				2		24.16	69.54	6.30	1.19						8,172	14,710
				3		25.78	74.22		1.27						8,721	15,698
Same (face of old main heading, 4-foot 8½-inch bed, 4-foot 4¾-inch cut).	274	12151	A	1	2.81	23.54	66.65	7.00	1.25					2.2	7,856	14,141
				2		24.22	68.58	7.20	1.29						8,083	14,549
				3		26.10	73.90		1.39						8,710	15,678
Same (face of second right cross heading, 4-foot ½-inch bed, 3-foot 9-inch cut).	274	12166	A	1	2.88	23.92	66.34	6.86	1.33					2.2	7,845	14,121
				2		24.63	68.31	7.06	1.37						8,078	14,540
				3		26.50	73.50		1.47						8,692	15,646
Same (face of left heading 3, 3-foot 8-inch bed, 3-foot 4½-inch cut).	274	12167	A	1	3.26	23.50	64.78	8.46	1.73					2.7	7,644	13,759
				2		24.29	66.96	8.75	1.79						7,902	14,224
				3		26.62	73.38		1.96						8,660	15,588

Same (composite of samples 12150, 12151, 12166 and 12167).	274	12168	A	1	2.89	23.67	66.34	7.10	1.37	5.02	79.49	1.30	5.72	2.3	7,837	14,107
				2	....	24.38	68.31	7.31	1.41	4.84	81.86	1.34	3.24	....	8,071	14,528
				3	....	26.30	73.70	....	1.52	5.22	88.32	1.45	3.49	....	8,708	15,674
Same (pillar in room 16, off left entry 3, 4-foot 4½-inch bed, 4-feet 4½-inch cut).	274	12169	A	1	3.42	23.16	67.27	6.15	1.62	5.10	79.55	1.28	6.30	2.8	7,839	14,110
				2	....	23.98	69.65	6.37	1.68	4.89	82.37	1.33	3.36	....	8,117	14,611
				3	....	25.61	74.39	....	1.79	5.22	87.97	1.42	3.60	....	8,669	15,604
1 mile south of; Pennsylvania No. 12 mine, Lower Freeport or D bed (face of original old main heading, 5,800 feet from mine mouth, 3-foot 1½-inch bed, 3-foot cut).	274	12152	A	1	2.28	25.33	64.46	7.93	2.14	....	....	....	....	1.6	7,777	13,999
				2	....	25.92	65.97	8.11	2.19	....	....	....	....	....	7.958	14.324
				3	....	28.21	71.79	....	2.38	....	....	....	....	....	8,661	15,590
Same (face of entry 5, off main heading, 4-foot ⅝-inch bed, 3-foot 10⅝-inch cut).	274	12153	A	1	3.00	22.49	67.52	6.99	2.02	....	....	....	....	2.3	7,828	14,090
				2	....	23.18	69.61	7.21	2.08	....	....	....	....	....	8,070	14,526
				3	....	24.98	75.02	....	2.24	....	....	....	....	....	8,697	15,655
Same (face of right heading 4, 1½ miles from mine mouth, 3-foot 11½-inch bed, 3-foot 8½-inch cut).	274	12154	A	1	2.55	24.09	66.39	6.97	1.56	....	....	....	....	1.9	7,861	14,150
				2	....	24.72	68.13	7.15	1.60	....	....	....	....	....	8,067	14,521
				3	....	26.62	73.38	....	1.72	....	....	....	....	....	8,688	15,638
Same (face of room 1, off entry 1, off right heading 3, 4-foot 4½-inch bed, 4-foot 2½-inch cut).	274	12155	A	1	2.63	23.31	66.07	7.99	1.58	....	....	....	....	2.2	7,750	13,950
				2	....	23.94	67.85	8.21	1.62	....	....	....	....	....	7,959	14,326
				3	....	26.08	73.92	....	1.76	....	....	....	....	....	8,671	15,608
Same (face of right entry 3, off main heading, 4-foot 3-inch bed, 3-foot 9-inch cut).	274	12156	A	1	2.78	22.50	67.47	7.25	1.74	....	....	....	....	2.1	7,821	14,078
				2	....	23.14	69.40	7.46	1.79	....	....	....	....	....	8,045	14,481
				3	....	25.01	74.99	....	1.93	....	....	....	....	....	8,693	15,647
Same (composite of samples 12152–12156).........	274	12157	A	1	2.73	23.61	66.18	7.48	1.84	4.88	78.80	1.31	5.69	2.0	7,797	14,035
				2	....	24.27	68.04	7.69	1.89	4.71	81.01	1.35	3.35	....	8,016	14,429
				3	....	26.29	73.71	....	2.05	5.10	87.76	1.46	3.63	....	8,684	15,631
Johnstown, 3 miles south of; Valley No. 1 mine, Upper Kittanning or C bed (face of room 11 in Andy's heading, 1,000 feet west of tipple No. 2, 4-foot bed, 3-foot 11¾-inch cut).	275	W19563	A	1	2.0	14.0	73.6	10.4	2.05	....	....	....	....	....	7,667	13,800
				2	....	14.3	75.1	10.6	2.10	....	....	....	....	....	7,817	14,070
				3	....	16.0	84.0	....	2.35	....	....	....	....	....	8,744	15,740
Same (face of room 21, left heading 7, 3,400 feet southeast of mine mouth, 4-foot 2-inch bed and cut).	275	W19564	A	1	1.9	14.0	74.8	9.3	2.25	....	....	....	....	....	7,733	13,920
				2	....	14.3	76.2	9.5	2.30	....	....	....	....	....	7.883	14,190
				3	....	15.8	84.2	....	2.54	....	....	....	....	....	8.711	15,680
Same (face of room 4, right heading 8, 3,600 feet southeast of mine mouth, 4-foot 1¾-inch cut.	275	W19566	A	1	1.8	14.5	76.2	7.5	.70	....	....	....	....	....	7,950	14,310
				2	....	14.8	77.6	7.6	.70	....	....	....	....	....	8,100	14,580
				3	....	16.0	84.0	....	.76	....	....	....	....	....	8,767	15,780
Same (rib of main air course, 150 feet beyond right heading 12, 4-foot 4½-inch bed, 4-foot 3⅞-inch cut).	275	W19567	A	1	2.4	14.4	75.3	7.9	1.00	....	....	....	....	....	7,861	14,150
				2	....	14.7	77.2	8.1	1.05	....	....	....	....	....	8,050	14,490
				3	....	16.0	84.0	....	1.14	....	....	....	....	....	8,761	15,770
Same (composite of samples W19563, W19564, W19566, and W19567).	275	12213	A	1	1.32	14.63	75.24	8.81	1.57	4.26	81.19	1.39	2.78	....	7,804	14,047
				2	....	14.83	76.24	8.93	1.59	4.17	82.28	1.41	1.62	....	7,909	14,236
				3	....	16.28	83.72	....	1.75	4.58	90.35	1.55	1.77	....	8,685	15,633
Same (chain pillar, 4,200 feet northeast of mine-mouth, 3-foot 9⅜-inch bed and cut).	275	W19565	A	1	2.3	14.3	74.6	8.8	2.45	....	....	....	....	....	7,739	13,930
				2	....	14.6	76.4	9.0	2.50	....	....	....	....	....	7,922	14,260
				3	....	16.0	84.0	....	2.75	....	....	....	....	....	8,706	15,670

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CAMBRIA COUNTY—continued.																
Nanty Glo, 1 mile north of; Lincoln No. 1 mine; Lower Kittanning, Miller, or B bed (face of new main heading, 3-foot 4-inch bed and cut).	276	12180	A	1	3.03	19.35	71.18	6.44	1.84	......	......	......	......	2.4	7,936	14,285
				2	......	19.95	73.41	6.64	1.90	......	......	......	......	......	8,184	14,731
				3	......	21.37	78.63	......	2.04	......	......	......	......	......	8,766	15,779
Same (face of right entry 2, 3-foot 5-inch bed and cut).	276	12181	A	1	3.28	18.01	72.23	6.48	1.70	......	......	......	......	2.6	7,902	14,224
				2	......	18.62	74.68	6.70	1.76	......	......	......	......	......	8,170	14,706
				3	......	19.96	80.04	......	1.89	......	......	......	......	......	8,757	15,763
Same (face of right entry 4, 3-foot 4-inch bed and cut).	276	12182	A	1	2.84	19.60	71.48	6.08	1.68	......	......	......	......	2.4	7,980	14,364
				2	......	20.17	73.57	6.26	1.73	......	......	......	......	......	8,213	14,783
				3	......	21.52	78.48	......	1.85	......	......	......	......	......	8,762	15,772
Same (face of left entry 7, 3-foot 6-inch bed and cut).	276	12183	A	1	2.93	19.69	71.41	5.97	1.58	......	......	......	......	2.5	7,971	14,348
				2	......	20,28	73.57	6.15	1.63	......	......	......	......	......	8,212	14,782
				3	......	21.61	78.39	......	1.74	......	......	......	......	......	8,750	15,750
Same (face of left entry 9, 3-foot 5-inch bed and cut).	276	12184	A	1	2.74	19.07	71.20	6.99	2.21	......	......	......	......	2.3	7,881	14,186
				2	......	19.61	73.21	7.18	2.27	......	......	......	......	......	8,103	14,585
				3	......	21.13	78.87	......	2.45	......	......	......	......	......	8,730	15,714
Same (composite of samples 12180, 12181, 12182, 12183, and 12184).	276	12185	A	1	2.84	19.78	70.89	6.49	1.85	4.87	80.83	1.32	4.64	2.4	7,936	14,285
				2	......	20.36	72.96	6.68	1.90	4.68	83.19	1.36	2.19	......	8,168	14,702
				3	......	21.82	78.18	......	2.04	5.02	89.15	1.46	2.33	......	8,753	15,755
One-half mile southeast of; Springfield No. 1 mine, Lower Kittanning or B bed (face of left entry 4, 2,700 feet from mine mouth, 3-foot 4-inch bed and cut).	276	12128	A	1	3.31	17.71	71.87	7.11	2.00	......	......	......	......	2.8	7,841	14,114
				2	......	18.32	74.33	7.35	2.07	......	......	......	......	......	8,109	14,596
				3	......	19.77	80.23	......	2.23	......	......	......	......	......	8,753	15,755
Same (face of main entry, 3,500 feet from mine mouth, 3-foot 8-inch bed and cut).	276	12129	A	1	4.31	16.57	72.57	6.55	2.31	......	......	......	......	3.7	7,795	14,031
				2	......	17.32	75.83	6.85	2.41	......	......	......	......	......	8,146	14,663
				3	......	18.59	81.41	......	2.59	......	......	......	......	......	8,745	15,741
Same (face of third crosscut off dip heading, 2,500 feet from mine mouth, 3-foot 7-inch bed and cut).	276	12130	A	1	3.09	17.11	73.28	6.52	2.35	......	......	......	......	2.5	7,901	14,222
				2	......	17.66	75.61	6.73	2.43	......	......	......	......	......	8,153	14,675
				3	......	18.94	81.06	......	2.61	......	......	......	......	......	8,741	15,734
Same (face of left entry 2, 3,000 feet from mine mouth, 3-foot 8-inch bed and cut).	276	12131	A	1	2.98	20.78	69.93	6.31	1.88	......	......	......	......	2.4	7,925	14,265
				2	......	21.42	72.08	6.50	1.94	......	......	......	......	......	8,168	14,702
				3	......	22.91	77.09	......	2.07	......	......	......	......	......	8,736	15,725

Same (composite of samples 12128, 12129, 12130, 12131).	277	12132	A	1	3.48	17.97	71.73	6.82	2.22	4.74	80.12	1.20	4.90	2.9	7,857	14,143
				2	....	18.62	74.31	7.07	2.30	4.51	83.01	1.24	1.87	....	8,141	14,654
				3	....	20.04	79.96	....	2.48	4.86	89.33	1.33	2.00	....	8,761	15,770
Same (pillar in room 3, off left entry 2, 3-foot 9-inch bed and cut).	276	12133	A	1	3.19	17.22	73.83	5.76	1.97	4.79	81.30	1.21	4.97	2.5	7,991	14,384
				2	....	17.79	76.26	5.95	2.04	4.59	83.98	1.25	2.19	....	8,255	14,859
				3	....	18.92	81.08	....	2.17	4.88	89.30	1.33	2.32	....	8,778	15,800
Portage, 2 miles north of; Forge slope No. 1 mine, Upper Kittanning or C' bed (face of main south heading, 1 mile south of mine mouth, 3-foot 4½-inch bed and cut).	277	W20396	A	1	2.0	16.3	74.1	7.6	.55	....	....	....	....	....	7,872	14,170
				2	....	16.6	75.6	7.8	.55	....	....	....	....	....	8,033	14,460
				3	....	18.0	82.0	....	.60	....	....	....	....	....	8,711	15,680
Same (on rib, near face of left entry 7, off main south entry, 1 mile west of mine mouth, 3-foot 5-inch bed and cut).	277	W20397	A	1	1.8	18.3	70.0	9.9	2.55	....	....	....	....	....	7,656	13,780
				2	....	18.6	71.3	10.1	2.60	....	....	....	....	....	7,794	14,030
				3	....	20.7	79.3	....	2.99	....	....	....	....	....	8,672	15,610
Same (on rib, near face of right entry 2, off left entry 7, off main south entry, 4,500 feet northwest of mine mouth, 3-foot 5½-inch bed and cut).	277	W20398	A	1	1.8	18.1	70.8	9.3	2.60	....	....	....	....	....	7,722	13,900
				2	....	18.4	72.1	9.5	2.65	....	....	....	....	....	7,867	14,160
				3	....	20.3	79.7	....	2.93	....	....	....	....	....	8,694	15,650
Same (on rib, near face of right entry 1, off left entry 7, off main south heading, 5,000 feet southwest of mine mouth, 3-foot 7¾-inch bed and cut).	277	W20399	A	1	2.3	15.1	73.5	9.1	2.25	....	....	....	....	....	7,717	13,890
				2	....	15.5	75.2	9.3	2.30	....	....	....	....	....	7,900	14,220
				3	....	17.1	82.9	....	2.54	....	....	....	....	....	8,711	15,680
Same (face of main north heading, 3,000 feet north of mine mouth, 3-foot 5¼-inch bed and cut).	277	W20400	A	1	1.9	16.7	73.4	8.0	1.40	....	....	....	....	....	7,828	14,090
				2	....	17.0	74.8	8.2	1.45	....	....	....	....	....	7,978	14,360
				3	....	18.5	81.5	....	1.58	....	....	....	....	....	8,694	15,650
Same (on rib near face of right entry 3, off main north entry, 2,600 feet north of mine mouth, 3-foot 7-inch bed and cut).	277	W20401	A	1	2.1	17.0	72.5	8.4	1.00	....	....	....	....	....	7,772	13,990
				2	....	17.4	74.0	8.6	1.06	....	....	....	....	....	7,939	14,290
				3	....	19.0	81.0	....	1.16	....	....	....	....	....	8,683	15,630
Same (composite of samples W20396–W20401)....	278	12369	A	1	.94	18.41	71.73	8.92	1.86	4.36	80.10	1.23	3.53	....	7,823	14,081
				2	......	18.58	72.42	9.00	1.88	4.30	80.86	1.24	2.72	....	7,897	14,215
				3	....	20.42	79.58	....	2.07	4.73	88.86	1.36	2.98	....	8,678	15.620
1 mile east of; Miller No. 1 shaft; Lower Kittanning, Miller, or B bed (face of second right dip, 2,800 feet southwest of shaft, 3-foot 2-inch bed, 2-foot 9½-inch cut).	278	11355	A	1	2.94	15.81	75.92	5.33	.70	....	....	....	....	2.4	....	....
				2	....	16.29	78.22	5.49	.72	....	....	....	....	....	....	....
				3	....	17.24	82.76	....	.76	....	....	....	....	....	....	....
Same (face of left heading 3, 4,100 feet southeast of shaft, 3-foot 11¼-inch bed, 3-foot 7¼-inch cut).	278	11356	A	1	2.91	17.58	72.69	6.82	1.68	....	....	....	....	2.4	....	....
				2	....	18.11	74.87	7.02	1.73	....	....	....	....	....	....	....
				3	....	19.48	80.52	....	1.86	....	....	....	....	....	....	....
Same (pillar of A–1 heading, 2,000 feet from foot of shaft, 3-foot 5-inch bed, 3-foot 2¼-inch cut).	278	11357	A	1	1.85	19.83	71.53	6.79	1.49	....	....	....	....	1.4	....	....
				2	....	20.20	72.88	6.92	1.52	....	....	....	....	....	....	....
				3	....	21.70	78.30	....	1.63	....	....	....	....	....	....	....
Same (face of first right dip, 1,500 feet from foot of shaft, 3-foot 10¾-inch bed, 3-foot 4¾-inch cut).	278	11358	A	1	2.35	17.47	74.09	6.09	.73	....	....	....	....	1.8	....	....
				2	....	17.89	75.87	6.24	.75	....	....	....	....	....	....	....
				3	....	19.08	80.92	....	.80	....	....	....	....	....	....	....
Same (face of left heading 1, 3,000 feet from foot of shaft, 3-foot 6-inch bed, 3-foot ½-inch cut).	278	11359	A	1	3.43	17.69	72.25	6.63	1.41	....	....	....	....	2.9	....	....
				2	....	18.32	74.81	6.87	1.46	....	....	....	....	....	....	....
				3	....	19.67	80.33	....	1.57	....	....	....	....	....	....	....
Same (composite of samples 11355–11359).......	278	11360	A	1	2.87	17.63	73.21	6.29	1.22	4.51	81.69	1.23	5.06	2.2	7,940	14,292
				2	....	18.15	75.37	6.48	1.26	4.31	84.10	1.27	2.58	....	8,176	14,713
				3	....	19.41	80.59	....	1.35	4.61	89.93	1.36	2.75	....	8,740	15,732

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CAMBRIA COUNTY—continued.																
Portage, 2¼ miles east of; Plymouth No. 1 mine, Upper Kittanning or C' bed (face of dip 5, 300 feet from main heading, 3-foot 7½-inch bed, 3-foot 7-inch cut).	279	W17110	A	1	3.3	17.5	72.6	6.6	.70	......	......	......	......	......	7,861	14,150
				2	......	18.0	75.2	6.8	.75	......	......	......	......	......	8,133	14,640
				3	......	19.3	80.7	......	.80	......	......	......	......	......	8,728	15,710
Same (face of left entry 4, 2,000 feet from main heading, 3-foot 8¼-inch bed, 3-foot 8-inch cut).	279	W17111	A	1	3.5	17.5	70.7	8.3	1.50	......	......	......	......	......	7,694	13,850
				2	......	18.1	73.3	8.6	1.60	......	......	.....	......	......	7,972	14,350
				3	......	19.8	80.2	......	1.75	......	......	......	......	......	8,722	15,700
Same (face of main heading, 250 feet from left entry 8, 3-foot ½-inch cut).	279	W17112	A	1	3.3	16.5	72.9	7.3	.70	......	......	......	......	......	7,817	14,070
				2	......	17.0	75.5	7.5	.70	......	......	......	......	......	8,083	14,550
				3	......	18.4	81.6	......	.76	......	......	......	......	......	8,739	15,730
Same (composite samples of W17110, W17111, and W17112).	279	11705	A	1	1.95	......	......	7.60	1.05	4.45	78.35	1.18	7.37	......	......	......
				2	......	......	......	7.75	1.07	4.31	79.91	1.20	5.76	......	......	......
				3	......	......	......	......	1.16	4.67	86.62	1.30	6.25	......	......	......
1 mile east of; Sonman No. 2 shaft, Lower Kittanning or B bed (pillar near face of room 23, first right off plane, 3,000 feet southeast of shaft, 3-foot 11-inch bed, 3-foot 7-inch cut).	280	W19689	A	1	2.5	15.3	76.0	6.2	.65	......	......	......	......	......	8,039	14,470
				2	......	15.7	77.9	6.4	.65	......	......	......	......	......	8,239	14,830
				3	......	16.8	83.2	......	.69	......	......	......	......	......	8,800	15,840
Same (face of "No. 32 crook," off main north heading, 4-foot 3¾-inch bed, 3-foot 7¼-inch cut).	280	W19691	A	1	2.6	16.3	74.6	6.5	1.65	......	......	......	......	......	7,956	14,320
				2	......	16.7	76.6	6.7	1.70	......	......	......	......	......	8,172	14,710
				3	......	17.9	82.1	......	1.82	......	......	......	......	......	8,756	15,760
Same (face of "No. 28 crook," left heading 1, off dip, off main south heading, 3-foot 11¾-inch bed, 3-foot 4¾-inch cut).	280	W19692	A	1	2.5	15.9	76.1	5.5	.65	......	......	......	......	......	8,083	14,550
				2	......	16.3	78.1	5.6	.65	......	......	......	......	......	8,286	14,915
				3	......	17.3	82.7	......	.69	......	......	......	......	......	8,778	15,800
Same (composite of samples W19689, W19691, and W19692).	280	12217	A	1	1.43	16.92	75.22	6.43	1.08	4.50	83.40	1.30	3.29	......	8,087	14,557
				2	......	17.17	76.31	6.52	1.10	4.40	84.61	1.32	2.05	......	8,204	14,767
				3	......	18.37	81.63	......	1.18	4.71	90.51	1.41	2.19	......	8,776	15,797
Same (face of room 8, left heading 2, off dip off main south heading, 3-foot 3-inch bed, 3-foot ½-inch cut).	280	W19688	A	1	1.7	16.3	74.4	7.6	.65	......	......	......	......	......	7,933	14,280
				2	......	16.6	75.7	7.7	.65	......	......	......	......	......	8,072	14,530
				3	......	18.0	82.0	......	.70	......	......	......	......	......	8,744	15,740

Same (face of room 13, off left heading 1, off dip, off main south heading, 4-foot 4½-inch bed, 3-foot 10-inch cut).	280	W19690	A	1	2.5	15.4	76.6	5.5	1.15						8,094	14,570
				2		15.8	78.6	5.6	1.20						8,300	14,940
				3		16.7	83.3		1.27						8,794	15,830
Same (face of room 10, first right off plane 17, off main north heading, 4-foot 5-inch bed, 3-foot 9½-inch cut).	280	W19693	A	1	2.2	16.1	75.0	6.7	1.30						7,978	14,360
				2		16.5	76.6	6.9	1.35						8,156	14,680
				3		17.7	82.3		1.45						8,756	15,760
Same (face of right heading 3, off main dip, off main north heading, 4-foot 4-inch bed, 3-foot 10½-inch cut).	280	W19694	A	1	4.2	15.4	74.9	5.5	.65						7,967	14,340
				2		16.1	78.2	5.7	.70						8,317	14,970
				3		17.1	82.9		.74						8,817	15,870
Same (composite of samples W19688, W19690, W19693, and W19694).	280	12205	A	1	1.44	15.96	76.34	6.26	98	4.44	83.35	1.19	3.78		8,101	14,582
				2		16.19	77.46	6.35	.99	4.34	84.57	1.21	2.54		8,219	14,794
				3		17.29	82.71		1.06	4.63	90.30	1.29	2.72		8,776	15,797
Spangler, 2 miles northwest of; Pennsylvania No. 21 mine, D or Lower Freeport bed (face of main heading, 5,000 feet southwest of mine mouth, 3-foot 9-inch bed, 3-foot 7-inch cut.	281	12144	A	1	4.54	22.74	67.62	5.10	.63					3.8	7,867	14,161
				2		23.82	70.84	5.34	.66						8,241	14,834
				3		25.16	74.84		.70						8,706	15,671
Same (face of second main entry, 6,500 feet from mine mouth, 3-foot 5¾-inch bed, 2-foot 10-inch cut).	281	12145	A	1	2.40	25.79	65.82	5.99	1.18					1.4	7,965	14,337
				2		26.42	67.44	6.14	1.21						8,161	14,690
				3		28.15	71.85		1.29						8,695	15,651
Same (face of back heading 17, 5,900 feet west of mine mouth, 3-foot 6-inch bed, 2-foot 8¾-inch cut).	281	12146	A	1	3.02	26.59	64.34	6.05	1.74					2.1	7,902	14,224
				2		27.42	66.34	6.24	1.79						8,148	14,666
				3		29.25	70.75		1.91						8,691	15,644
Same (face of right entry 4, off second main entry, 6,300 feet east of mine mouth, 3-foot 7½-inch bed, 3-foot 5-inch cut).	281	12147	A	1	2.65	26.48	62.86	8.01	1.56					1.9	7,771	13,988
				2		27.20	64.57	8.23	1.60						7,982	14,368
				3		29.64	70.36		1.74						8,698	15,656
Same (composite of samples 12144–12147	281	12148	A	1	3.14	26.01	64.40	6.45	1.37	5.08	79.55	1.30	6.25	2.3	7,866	14,159
				2		26.85	66.49	6.66	1.41	4.88	82.13	1.34	3.58		8,121	14,618
				3		28.77	71.23		1.51	5.23	87.99	1.44	3.83		8,701	15,662
2 miles northwest of; Pennsylvania No. 22 mine, Lower Freeport or D bed (face of ninth main entry, 7,200 feet southwest of mine mouth, 3-foot 9-inch cut).	281	12126	A	1	4.86	21.85	67.48	5.81	1.01					3.9	7,804	14,047
				2		22.97	70.92	6.11	1.06						8,203	14,765
				3		24.47	75.53		1.13						8,737	15,727
Same (rib of room 9, off right entry 4, off ninth main entry, 6,200 feet southwest of mine mouth, 3-foot 7½-inch cut).	281	12127	A	1	2.55	22.53	68.11	6.81	1.20					1.7	7,894	14,209
				2		23.12	69.89	6.99	1.23						8,101	14,582
				3		24.86	75.14		1.32						8,710	15,678
Same (face of room 17, off right entry 6, off ninth main entry, 7,400 feet from mine mouth, 3-foot 9¾-inch cut).	281	12140	A	1	2.83	23.17	67.53	6.47	1.57					2.3	7,821	14,078
				2		23.84	69.50	6.66	1.62						8,049	14,488
				3		25.54	74.46		1.74						8,624	15,523
Same (face of main back heading, 7,100 feet from mine mouth, 3-foot 2-inch cut).	281	12141	A	1	2.70	23.73	66.86	6.71	1.39					2.0	7,904	14,227
				2		24.39	68.71	6.90	1.43						8,123	14,621
				3		26.20	73.80		1.54						8,725	15,705
Same (face of fourteenth right, off main heading, 7,200 feet from mine mouth, 3-foot 1½-inch cut).	281	12142	A	1	2.61	23.74	67.62	6.03	.95					1.9	7,968	14,342
				2		24.38	69.43	6.19	.98						8,182	14,728
				3		25.99	74.01		1.04						8,722	15,700
Same (composite of samples 12126, 12127, 12140, 12141, and 12142).	282	12143	A	1	3.08	22.77	67.60	6.55	1.24	4.90	80.54	1.36	5.41	2.4	7,856	14,141
				2		23.49	69.75	6.76	1.28	4.71	83.10	1.40	2.75		8,106	14,591
				3		25.19	74.81		1.37	5.05	89.12	1.50	2.96		8,694	15,649

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CAMBRIA COUNTY—continued.																
Twin Rocks, near: Big Bend No. 1 mine, Miller, B, or Lower Kittanning bed (face of room 11, off drainage heading, 2,600 feet northeast of main opening, 3-foot 7½-inch bed and cut).	282	W19668	A	1	2.4	20.0	71.7	5.9	1.70	......	......	......	......	......	8,094	14,570
				2	......	20.5	73.5	6.0	1.75	......	......	......	......	......	8,294	14,930
				3	......	21.8	78.2	......	1.86	......	......	......	......	......	8,828	15,890
Same (face of water-level heading, 2,000 feet northeast of main opening, 3-foot 6½-inch bed and cut).	282	W19669	A	1	1.9	19.7	72.4	6.0	.60	......	......	......	......	......	8,078	14,540
				2	......	20.1	73.8	6.1	.60	......	......	......	......	......	8,239	14,830
				3	......	21.4	78.6	......	.64	......	......	......	......	......	8,772	15,790
Same (composite of samples W19668 and W19669)	282	12215	A	1	1.29	20.56	72.15	6.00	1.74	4.75	82.96	1.33	3.22	......	8,122	14,620
				2	......	20.83	73.09	6.08	1.76	4.67	84.05	1.35	2.09	......	8,228	14,810
				3	......	22.18	77.82	......	1.87	4.97	89.49	1.44	2.23	......	8,760	15,768
Same (pillar opposite room 16, off Claghorn section, 3,000 feet east of main opening, 3-foot 7½-inch bed).	282	W19672	A	1	2.0	19.5	73.0	5.5	1.50	......	......	......	......	......	8,078	14,540
				2	......	19.9	74.5	5.6	1.55	......	......	......	......	......	8,244	14,840
				3	......	21.1	78.9	......	1.64	......	......	......	......	......	8,739	15,730
Same (pillar to left of main heading, 2,500 feet east of main opening, 3-foot 7½-inch bed).	282	W19674	A	1	2.2	20.0	72.7	5.1	1.45	......	......	......	......	......	8,156	14,680
				2	......	20.5	74.3	5.2	1.50	......	......	......	......	......	8,344	15,020
				3	......	21.6	78.4	......	1.58	......	......	......	......	......	8,800	15,840
Same (pillar to left of main heading, opposite right headings 6 and 7, 2,000 feet east of main opening, 4-foot 3-inch bed and cut).	282	W19676	A	1	2.6	20.3	72.2	4.9	1.15	......	......	......	......	......	8,106	14,590
				2	......	20.8	74.2	5.0	1.20	......	......	......	......	......	8,322	14,980
				3	......	21.9	78.1	......	1.26	......	......	......	......	......	8,761	15,770
Same (composite of samples W19672, W19674, and W19676).	282	12208	A	1	1.32	20.33	73.01	5.34	1.39	4.66	83.45	1.33	3.83	......	8,201	14,762
				2	......	20.60	73.99	5.41	1.41	4.57	84.57	1.35	2.69	......	8,311	14,959
				3	......	21.78	78.22	......	1.49	4.83	89.41	1.43	2.84	......	8,786	15,815
1 mile north of: Big Bend No. 6 mine, Miller, B, or Lower Kittanning bed (room 1, left side of right heading 1, off No. 9 drift, 900 feet south of No. 9 opening, 3-foot 9½-inch bed, 3-foot 9½-inch cut).	283	W19670	A	1	2.7	18.9	72.6	5.8	1.75	......	......	......	......	......	8,017	14,430
				2	......	19.4	74.6	6.0	1.80	......	......	......	......	......	8,239	14,830
				3	......	20.6	79.4	......	1.91	......	......	......	......	......	8,767	15,780
Same (face of heading 13, 325 feet from outcrop and 3,500 feet southeast from main opening, 3-foot 9½-inch bed, 3-foot 8½-inch cut).	283	W19673	A	1	3.2	18.7	73.2	4.9	.95	......	......	......	......	......	8,011	14,420
				2	......	19.3	75.6	5.1	1.00	......	......	......	......	......	8,278	14,900
				3	......	20.3	79.7	......	1.05	......	......	......	......	......	8,722	15,700
Same (face of room 10 on left side of No. 9 drift, 700 feet southwest of No. 9 opening, 3-foot 8½-inch bed, 3-foot 8½-inch cut).	283	W19677	A	1	2.6	20.0	72.1	5.3	1.00	......	......	......	......	......	8,061	14,510
				2	......	20.5	74.1	5.4	1.05	......	......	......	......	......	8,272	14,890
					......	21.7	78.3	......	1.11	......	......	......	......	......	8,739	15,730

Same (composite of samples W19670, W 19673, and W19677).	283	12227	A	1	1.54	20.67	72.37	5.42	1.40	4.73	83.20	1.38	3.87	....	8,138	14,648
				2	....	20.99	73.51	5.50	1.42	4.63	84.50	1.40	2.55	....	8,265	14,877
				3	....	22.21	77.79	....	1.50	4.90	89.42	1.48	2.70	....	8,746	15,743
Same (pillar between rooms 23 and 24, off main heading, 1,500 feet northeast of main opening, 3-foot 7½-inch bed).	283	W19671	A	1	2.8	19.4	72.5	5.3	1.10	....	....	....	....	....	8,006	14,410
				2	....	19.9	74.7	5.4	1.15	....	....	....	....	....	8,233	14,820
				3	....	21.0	79.0	....	1.22	....	....	....	....	....	8,717	15,690
Same (pillar between rooms 27 and 28, off main heading, 2,000 feet northeast of main opening, 3-foot 9½-inch cut).	283	W19675	A	1	2.2	19.7	72.7	5.4	1.10	....	....	....	....	....	8,106	14,590
				2	....	20.1	74.4	5.5	1.15	....	....	....	....	....	8,289	14,920
				3	....	21.3	78.7	....	1.22	....	....	....	....	....	8,767	15,780
Same (composite of samples W19671 and W19675)..	283	12207	A	1	1.47	20.18	72.91	5.44	1.20	4.75	83.43	1.27	3.91	....	8,169	14,704
				2	....	20.48	74.00	5.52	1.22	4.66	84.67	1.29	2.64	....	8,291	14,924
				3	....	21.68	78.32	....	1.29	4.93	89.61	1.37	2.80	....	8,775	15,795
Commercial No. 3 mine, Miller or B bed (face of main heading, 6,200 feet northwest of mine mouth, 5-foot ¼-inch bed, 3-foot 10½-inch cut).	284	W20477	A	1	3.1	18.3	71.6	7.0	2.10	....	....	....	....	....	7,867	14,160
				2	....	18.9	73.9	7.2	2.15	....	....	....	....	....	8,117	14,610
				3	....	20.4	79.6	....	2.32	....	....	....	....	....	8,744	15,740
Same (face of right heading 7, 450 feet off main entry and 5,600 feet northwest of mine mouth, 3-foot 6¾-inch bed, 3-foot 6-inch cut).	284	W20479	A	1	2.1	20.2	70.4	7.3	2.75	....	....	....	....	....	7,906	14,230
				2	....	20.6	71.9	7.5	2.80	....	....	....	....	....	8,072	14,530
				3	....	22.3	77.7	....	3.03	....	....	....	....	....	8,728	15,710
Same (face of left entry 7, 700 feet off main entry and 5,300 feet northwest of mine mouth, 3-foot 11¾-inch bed and cut).	284	W20480	A	1	2.9	17.8	71.4	7.9	.60	....	....	....	....	....	8,028	14,450
				2	....	18.3	73.6	8.1	.60	....	....	....	....	....	8,267	14,880
				3	....	19.9	80.1	....	.65	....	....	....	....	....	8,800	15,840
Same (face of right heading 5, 5,000 feet off main entry and 4,200 feet north of mine mouth, 3-foot 8½-inch bed and cut).	284	W20481	A	1	2.2	19.4	72.7	5.7	1.80	....	....	....	....	....	8,100	14,580
				2	....	19.8	74.4	5.8	1.85	....	....	....	....	....	8,278	14,900
				3	....	21.0	79.0	....	1.96	....	....	....	....	....	8,789	15,820
Same (composite of samples W20477, W20479, W20480, and W20481).	284	12377	A	1	.82	20.42	72.11	6.65	2.35	4.50	81.89	1.22	3.39	....	8,083	14,549
				2	....	20.59	72.70	6.71	2.37	4.45	82.57	1.23	2.67	....	8,150	14,670
				3	....	22.07	77.93	....	2.54	4.77	88.51	1.32	2.86	....	8,736	15,725
Same (pillar on right heading 4, 5,000 feet off main entry and 4,500 feet northeast of mine mouth, 3-foot 6-inch bed, 3-foot 5¾-inch cut).	284	W20478	A	1	1.8	20.0	71.5	6.7	1.70	....	....	....	....	....	8,011	14,420
				2	....	20.4	72.8	6.8	1.75	....	....	....	....	....	8,156	14,680
				3	....	21.9	78.1	....	1.88	....	....	....	....	....	8,756	15,760
Commercial No. 4 mine, lower Kittanning or B bed (face of main entry 3, off No. 4 slope, 3-foot 7½-inch bed and cut).	285	W17061	A	1	3.3	17.0	73.9	5.8	1.60	....	....	....	....	....	7,978	14,360
				2	....	17.5	76.5	6.0	1.70	....	....	....	....	....	8,250	14,850
				3	....	18.6	81.4	....	1.81	....	....	....	....	....	8,778	15,800
Same (100 feet from face of main heading, 5,200 feet north of mine mouth, 3-foot 8-inch bed and cut).	285	W20501	A	1	3.8	18.1	71.9	6.2	1.85	....	....	....	....	....	7,878	14,180
				2	....	18.8	74.8	6.4	1.95	....	....	....	....	....	8,189	14,740
				3	....	20.1	79.9	....	2.08	....	....	....	....	....	8,744	15,740
Same (face of east entry 6, off right entry 3, off main entry, 4,000 feet northeast of mine mouth, 3-foot 8¾-inch bed and cut).	285	W20505	A	1	2.4	19.0	72.3	6.3	1.85	....	....	....	....	....	7,956	14,320
				2	....	19.5	74.0	6.5	1.90	....	....	....	....	....	8,156	14,680
				3	....	20.9	79.1	....	2.03	....	....	....	....	....	8,722	15,700
Same (rib near face of east entry 7, off right entry 3, off main entry, 4,800 feet northeast of mine mouth, 3-foot 10¾-inch bed and cut).	285	W20506	A	1	3.0	18.3	73.1	5.6	1.45	....	....	....	....	....	8,011	14,420
				2	....	18.9	75.3	5.8	1.50	....	....	....	....	....	8,256	14,860
				3	....	20.1	79.9	....	1.59	....	....	....	....	....	8,761	15,770
Same (face of right entry 3, off main entry, 4,900 feet northeast of mine mouth, 3-foot 7-inch cut).	285	W20508	A	1	3.3	18.2	72.9	5.6	1.75	....	....	....	....	....	7,961	14,330
				2	....	18.8	75.4	5.8	1.80	....	....	....	....	....	8,239	14,830
				3	....	20.0	80.0	....	1.91	....	....	....	....	....	8,750	15,750
Same (composite of samples W20501, W20505, W20506, and W20508).	285	12364	A	1	.89	19.73	73.30	6.08	1.95	4.58	83.16	1.28	2.95	....	8,090	14,562
				2	....	19.91	73.96	6.13	1.97	4.52	83.91	1.29	2.18	....	8,163	14,693
				3	....	21.21	78.79	....	2.10	4.82	89.39	1.37	2.32	....	8,696	15,653
Same (sixth pillar on east entry 9, off right entry 2, off main entry, 3,800 feet northeast of mine mouth, 3-foot 4¾-inch cut).	285	W20503	A	1	2.8	18.6	72.9	5.7	1.55	....	....	....	....	....	7,983	14,370
				2	....	19.1	75.0	5.9	1.60	....	....	....	....	....	8,217	14,790
				3	....	20.3	79.7	....	1.70	....	....	....	....	....	8,733	15,720

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CAMBRIA COUNTY—continued.																
Twin Rocks, near; Big Bend No. 1 mine, Miller, B, or Lower Kittanning bed (face of room 11, off drainage heading, 2,600 feet northeast of main opening, 3-foot 7½-inch bed and cut).	282	W19668	A	1	2.4	20.0	71.7	5.9	1.70						8,094	14,570
				2		20.5	73.5	6.0	1.75						8,294	14,930
				3		21.8	78.2		1.86						8,828	15,890
Same (face of water-level heading, 2,000 feet northeast of main opening, 3-foot 6¾-inch bed and cut).	282	W19669	A	1	1.9	19.7	72.4	6.0	.60						8,078	14,540
				2		20.1	73.8	6.1	.60						8,239	14,830
				3		21.4	78.6		.64						8,772	15,790
Same (composite of samples W19668 and W19669)	282	12215	A	1	1.29	20.56	72.15	6.00	1.74	4.75	82.96	1.33	3.22		8,122	14,620
				2		20.83	73.09	6.08	1.76	4.67	84.05	1.35	2.09		8,228	14,810
				3		22.18	77.82		1.87	4.97	89.49	1.44	2.23		8,760	15,768
Same (pillar opposite room 16, off Claghorn section, 3,000 feet east of main opening, 3-foot 7½-inch bed).	282	W19672	A	1	2.0	19.5	73.0	5.5	1.50						8,078	14,540
				2		19.9	74.5	5.6	1.55						8,244	14,840
				3		21.1	78.9		1.64						8,739	15,730
Same (pillar to left of main heading, 2,500 feet east of main opening, 3-foot 7½-inch bed).	282	W19674	A	1	2.2	20.0	72.7	5.1	1.45						8,156	14,680
				2		20.5	74.3	5.2	1.50						8,344	15,020
				3		21.6	78.4		1.58						8,800	15,840
Same (pillar to left of main heading, opposite right headings 6 and 7, 2,000 feet east of main opening, 4-foot 3-inch bed and cut).	282	W19676	A	1	2.6	20.3	72.2	4.9	1.15						8,106	14,590
				2		20.8	74.2	5.0	1.20						8,322	14,980
				3		21.9	78.1		1.26						8,761	15,770
Same (composite of samples W19672, W19674, and W19676).	282	12208	A	1	1.32	20.33	73.01	5.34	1.39	4.66	83.45	1.33	3.83		8,201	14,762
				2		20.60	73.99	5.41	1.41	4.57	84.57	1.35	2.69		8,311	14,959
				3		21.78	78.22		1.49	4.83	89.41	1.43	2.84		8,786	15,815
1 mile north of; Big Bend No. 6 mine, Miller, B, or Lower Kittanning bed (room 1, left side of right heading 1, off No. 9 drift, 900 feet south of No. 9 opening, 3-foot 9½-inch bed, 3-foot 9½-inch cut).	283	W19670	A	1	2.7	18.9	72.6	5.8	1.75						8,017	14,430
				2		19.4	74.6	6.0	1.80						8,239	14,830
				3		20.6	79.4		1.91						8,767	15,780
Same (face of heading 13, 325 feet from outcrop and 3,500 feet southeast from main opening, 3-foot 9½-inch bed, 3-foot 8½-inch cut).	283	W19673	A	1	3.2	18.7	73.2	4.9	.95						8,011	14,420
				2		19.3	75.6	5.1	1.00						8,278	14,900
				3		20.3	79.7		1.05						8,722	15,700
Same (face of room 10 on left side of No. 9 drift, 700 feet southwest of No. 9 opening, 3-foot 8½-inch bed, 3-foot 8½-inch cut).	283	W19677	A	1	2.6	20.0	72.1	5.3	1.00						8,061	14,510
				2		20.5	74.1	5.4	1.05						8,272	14,890
						21.7	78.3		1.11						8,739	15,730

Same (composite of samples 12067, 12069, and 12070).	287	12071	A	1	3.24	20.65	68.34	7.77	2.08	4.89	77.85	1.25	6.16	2.5	7,726	13,907
				2	......	21.34	70.63	8.03	2.15	4.68	80.46	1.29	3.39	......	7,985	14,373
				3	......	23.20	76.80	......	2.34	5.09	87.48	1.40	3.69	......	8,682	15,626
Same (pillar at room 9, off left entry 5, off main entry, 5-foot 2¼-inch bed, 4 foot 1¾-inch cut).	287	12068	A	1	3.48	20.26	68.55	7.71	1.63	4.82	78.45	1.26	6.13	2.5	7,715	13,887
				2	......	20.99	71.02	7.99	1.69	4.59	81.28	1.31	3.14	......	7,994	14,389
				3	......	22.81	77.19	......	1.84	4.99	88.34	1.42	3.41	......	8,688	15,638
Same (composite of samples 12068, 12069, and 12070).	287	12190	A	1	3.04	22.92	67.32	6.72	1.54	4.95	79.49	1.33	5.97	2.4	7,851	14,132
				2	......	23.64	69.43	6.93	1.59	4.75	81.99	1.37	3.37	......	8,098	14,576
				3	......	25.40	74.60	......	1.71	5.10	88.10	1.47	3.62	......	8,701	15,662
¾ mile north of; Moshannon No. 10 mine, Lower Kittanning or B bed (on rib of room 18, off left entry 2, off right entry 4, 40 feet from left entry 2, 4-foot 6¾-inch bed, 3-foot 7½-inch cut).	287	12057	A	1	2.59	21.53	68.38	7.50	1.91	......	......	......	......	1.9	7,835	14,103
				2	......	22.10	70.20	7.70	1.96	......	......	......	......	......	8,043	14,477
				3	......	23.94	76.06	......	2.12	......	......	......	......	......	8,714	15,685
Same (face of room 21, off left main heading, 4-foot 5-inch bed, 3-foot 8½-inch cut).	287	12058	A	1	2.67	22.09	68.48	6.76	2.00	......	......	......	......	2.1	7,883	14,189
				2	......	22.70	70.35	6.95	2.05	......	......	......	......	......	8,099	14,578
				3	......	24.40	75.60	......	2.20	......	......	......	......	......	8,704	15,667
Same (face of room 16, off right main heading, near first crosscut to right, 4-foot 3¾-inch bed, 3-foot 8¼-inch cut).	287	12059	A	1	2.75	19.59	70.35	7.31	2.11	......	......	......	......	2.2	7,839	14,110
				2	......	20.14	72.34	7.52	2.17	......	......	......	......	......	8,061	14,510
				3	......	21.78	78.22	......	2.35	......	......	......	......	......	8,716	15,689
Same (face of right heading 1, 3-foot 8¾-inch bed, 3-foot 3-inch cut).	287	12060	A	1	3.80	19.98	69.09	7.13	1.73	......	......	......	......	3.2	7,779	14,002
				2	......	20.77	71.82	7.41	1.80	......	......	......	......	......	8,086	14,555
				3	......	22.43	77.57	......	1.94	......	......	......	......	......	8,733	15,719
Same (face of room 16, off right heading 2, 3-foot 5¼-bed, 2-foot 6¾-inch cut).	287	12061	A	1	3.03	21.25	67.95	7.77	2.48	......	......	......	......	2.5	7,750	13,950
				2	......	21.91	70.08	8.01	2.56	......	......	......	......	......	7,992	14,386
				3	......	23.82	76.18	......	2.78	......	......	......	......	......	8,688	15,638
Same (composite of samples 12057–12061)..........	288	12062	A	1	3.05	21.65	67.95	7.35	1.98	4.99	79.16	1.31	5.21	2.4	7,798	14,036
				2	......	22.33	70.09	7.58	2.04	4.80	81.65	1.35	2.58	......	8,044	14,479
				3	......	24.16	75.84	......	2.21	5.19	88.35	1.46	2.79	......	8,704	15,667
¾ mile south of; Weston mine, Lower Kittanning or B bed (face of left entry 4, off main entry, 4-foot 5⅝-inch bed, 3-foot 7½-inch cut).	288	12063	A	1	3.20	19.52	68.74	8.54	2.35	......	......	......	......	2.5	7,664	13,795
				2	......	20.17	71.01	8.82	2.43	......	......	......	......	......	7,918	14,252
				3	......	22.12	77.88	......	2.66	......	......	......	......	......	8,684	15,631
Same (rib of main heading, at left entry 7, 5-foot 1½-inch bed, 4-foot 4-inch cut).	288	12064	A	1	2.91	19.53	70.53	7.03	1.86	......	......	......	......	2.2	7,832	14,098
				2	......	20.12	72.64	7.24	1.92	......	......	......	......	......	8,067	14,521
				3	......	21.69	78.31	......	2.07	......	......	......	......	......	8,697	15,655
Same (composite of samples 12063 and 12064).....	288	12066	A	1	3.08	20.27	68.83	7.82	2.11	4.85	79.00	1.28	4.94	2.4	7,754	13,957
				2	......	20.91	71.02	8.07	2.18	4.65	81.51	1.32	2.27	......	8,001	14,402
				3	......	22.75	77.25	......	2.37	5.06	88.67	1.44	2.46	......	8,703	15,665
Same (pillar at room 8, off right entry 1, off main heading, 4-foot 7-inch cut).	288	12065	A	1	2.94	19.89	69.68	7.49	1.93	4.98	79.67	1.23	4.70	2.2	7,822	14,080
				2	......	20.49	71.79	7.72	1.99	4.79	82.08	1.27	2.15	......	8,059	14,506
				3	......	22.21	77.79	......	2.16	5.19	88.95	1.38	2.32	......	8,734	15,721
CLEARFIELD COUNTY.																
Boardman; Potts Run No. 3 mine, Lower Kittanning or B bed (face of right entry 3, off main entry, 1,400 feet southwest of mine mouth, 3-foot 7½-inch bed, 3-foot 6½-inch cut).	289	12093	A	1	2.74	20.75	67.85	8.66	1.59	......	......	......	......	2.0	7,724	13,903
				2	......	21.34	69.76	8.90	1.63	......	......	......	......	......	7,942	14,296
				3	......	23.42	76.58	......	1.79	......	......	......	......	......	8,718	15,692
Same (on rib, 10 feet from face of right entry 4, off main entry 1,700 feet southwest of mine mouth, 3-foot 7⅞-inch bed, 3-foot 7¼-inch cut).	289	12094	A	1	2.37	20.82	68.14	8.67	1.53	......	......	......	......	1.7	7,749	13,948
				2	......	21.33	69.79	8.88	1.57	......	......	......	......	......	7,937	14,287
				3	......	23.41	76.59	......	1.72	......	......	......	......	......	8,711	15,680
Same (face of left entry 3, off main entry, 1,680 feet northeast of mine mouth, 3-foot 6½-inch bed, 3-foot 6-inch cut).	289	12095	A	1	2.80	20.65	67.69	8.86	1.38	......	......	......	......	2.1	7,719	13,894
				2	......	21.24	69.64	9.12	1.42	......	......	......	......	......	7,941	14,294
				3	......	23.37	76.63	......	1.56	......	......	......	......	......	8,738	15,728

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CLEARFIELD COUNTY—continued.																
Boardman; Potts Run No. 3 mine, Lower Kittanning or B bed (face of main heading, 2,000 feet north of mine mouth, 3-foot 11½-inch bed, 3-foot 9-inch cut).	289	12096	A	1	3.38	20.50	67.75	8.37	1.08	......	......	......	......	2.7	7,697	13,855
				2	......	21.22	70.12	8.66	1.12	......	......	......	......	......	7,966	14,339
				3	......	23.23	76.77	......	1.23	......	......	......	......	......	8,721	15,698
Same (face of room 12, off right entry 2, off main entry, 3-foot 7½-inch bed, 3-foot 5½-inch cut).	289	12097	A	1	3.04	21.22	66.83	8.91	1.41	......	......	......	......	2.3	7,698	13,856
				2	......	21.89	68.92	9.19	1.45	......	......	......	......	......	7,940	14,292
				3	......	24.11	75.89	......	1.60	......	......	......	......	......	8,744	15,739
Same (composite of samples 12096–12097)	289	12098	A	1	2.95	21.29	66.92	8.84	1.35	4.74	78.51	1.19	5.37	2.2	7,723	13,901
				2	......	21.94	68.95	9.11	1.39	4.54	80.90	1.23	2.83	......	7,958	14,324
				3	......	24.14	75.86	......	1.53	4.99	89.01	1.35	3.12	......	8,755	15,759
Brisbin, 1 mile southwest of; Lenore No. 1 mine, Upper Freeport or E bed (face of left heading, off main heading, off No. 1 drift, 2-foot 7-inch bed and cut).	290	12046	A	1	3.00	21.59	67.61	7.80	.79	......	......	......	......	1.9	7,786	14,015
				2	......	22.26	69.70	8.04	.81	......	......	......	......	......	8,027	14,449
				3	......	24.21	75.79	......	.88	......	......	......	......	......	8,729	15,712
1 mile southwest of; Lenore No. 2 mine, Upper Freeport or E bed (face of left heading 3, off No. 2 drift, 2 foot 7½-inch bed and cut).	290	12044	A	1	3.14	21.77	66.12	8.97	1.08	......	......	......	......	2.0	7,690	13,842
				2	......	22.48	68.26	9.26	1.11	......	......	......	......	......	7,939	14,290
				3	......	24.77	75.23	......	1.22	......	......	......	......	......	8,749	15,748
Same (face of left heading 2, off No. 2 drift, 2-foot 6¼-inch bed and cut).	290	12045	A	1	2.83	21.78	67.89	7.50	.91	4.92	79.68	1.33	5.66	1.9	7,882	14,188
				2	......	22.41	69.87	7.72	.94	4.74	82.00	1.37	3.23	......	8,111	14,600
				3	......	24.29	75.71	......	1.02	5.14	88.86	1.48	3.50	......	8,788	15,818
Same (composite of samples 12044 and 12046)	290	12047	A	1	3.07	21.47	67.26	8.20	.94	4.80	78.48	1.23	6.35	2.0	7,757	13,963
				2	......	22.15	69.39	8.46	.97	4.60	80.97	1.27	3.73	......	8,003	14,405
				3	......	24.20	75.80	......	1.06	5.03	88.45	1.39	4.07	......	8,742	15,736
Madera, 1 mile east of; Morgan Run mine, Lower Kittanning or B bed (face of south entry 4, off right entry 5, 3-foot 5½-inch bed, 3-foot 4½-inch cut).	290	W20402	A	1	1.6	18.6	69.4	10.4	2.55	......	......	......	......	......	7,678	13,820
				2	......	18.9	70.5	10.6	2.60	......	......	......	......	......	7,800	14,040
				3	......	21.1	78.9	......	2.91	......	......	......	......	......	8,722	15,700
2 miles north of; Bucher mine, Lower Kittanning or B bed (left entry 9, off cross heading 1, 3,400 feet northeast of mouth of main entry, 3-foot 1¼-inch bed, 2-foot 11-inch cut).	290	W20435	A	1	2.3	18.7	68.5	10.5	1.00	......	......	......	......	......	7,606	13,690
				2	......	19.1	70.2	10.7	1.05	......	......	......	......	......	7,783	14,010
				3	......	21.4	78.6	......	1.18	......	......	......	......	......	8,711	15,680
Same (face of right heading 8, 3,800 feet northeast of mouth of main heading, 3-foot 3-inch bed, 3-foot 2½-inch cut).	290	W20436	A	1	2.1	20.0	68.9	9.0	1.45	......	......	......	......	......	7,767	13,980
				2	......	20.4	70.4	9.2	1.50	......	......	......	......	......	7,933	14,280
				3	......	22.5	77.5	......	1.65	......	......	......	......	......	8,739	15,730

Same (face of right heading 10, 4,500 feet northeast of mouth of main entry, 3-foot 3-inch bed, 3-foot 2-inch cut).	290	W 20437	A	1	2.4	19.9	68.2	9.5	1.20	....	....	....	....	....	7,700	13,860
				2	....	20.4	69.9	9.7	1.25	....	....	....	....	....	7,889	14,200
				3	....	22.6	77.4	....	1.38	....	....	....	....	....	8,739	15,730
Same (face of left heading 7, 3,000 feet northeast of mouth of main entry, 3-foot 6¾-inch bed, 3-foot 3½-inch cut).	290	W20438	A	1	2.3	19.5	70.2	8.0	1.15	....	....	....	....	....	7,839	14,110
				2	....	19.9	71.9	8.2	1.20	....	....	....	....	....	8,017	14,430
				3	....	21.7	78.3	....	1.31	....	....	....	....	....	8,733	15,720
Same (face of right heading 7, 3,200 feet northeast of mouth of main entry, 3-foot 1¼-inch cut).	290	W20439	A	1	2.3	20.4	69.0	8.3	1.20	....	....	....	....	....	7,756	13,960
				2	....	20.9	70.6	8.5	1.25	....	....	....	....	....	7,939	14,290
				3	....	22.8	77.2	....	1.37	....	....	....	....	....	8,772	15,790
Same (composite of samples W20435–W20439......	290	12376	A	1	.80	21.36	68.48	9.36	1.38	4.49	80.07	1.09	3.61	....	7,790	14,022
				2	....	21.53	69.03	9.44	1.39	4.44	80.72	1.10	2.91	....	7,853	14,135
				3	....	23.77	76.23	....	1.53	4.90	89.13	1.21	3.23	....	8,671	15,608
Same (face of east entry 3, off right entry 5, 3-foot 3¾-inch bed, 3-foot 2-inch cut).	290	W20403	A	1	1.9	19.1	68.5	10.5	1.75	....	....	....	....	....	7,606	13,690
				2	....	19.5	69.8	10.7	1.80	....	....	....	....	....	7,750	13,950
				3	....	21.8	78.2	....	2.02	....	....	....	....	....	8,678	15,620
Same (face of south entry 3, off right entry 5, 3-foot 7¾-inch bed, 3-foot 7½-inch cut).	290	W20404	A	1	2.0	18.2	67.4	12.4	3.15	....	....	....	....	....	7,411	13,340
				2	....	18.6	68.7	12.7	3.20	....	....	....	....	....	7,561	13,610
				3	....	21.3	78.7	....	3.67	....	....	....	....	....	8,661	15,590
Same (face of south entry 1, off right entry 5, 3-foot 5½-inch bed, 3-foot 3¾-inch cut).	290	W20405	A	1	2.0	18.7	68.3	11.0	3.30	....	....	....	....	....	7,550	13,590
				2	....	19.1	69.7	11.2	3.35	....	....	....	....	....	7,700	13,860
				3	....	21.5	78.5	....	3.77	....	....	....	....	....	8,672	15,610
Same (face of main heading, 3-foot 6½-inch bed, 3-foot 5½-inch cut).	290	W20406	A	1	1.9	17.3	70.5	10.3	3.50	....	....	....	....	....	7,589	13,660
				2	....	17.6	71.9	10.5	3.55	....	....	....	....	....	7,733	13,920
				3	....	19.7	80.3	....	3.97	....	....	....	....	....	8,639	15,550
Same (composite of samples W20402–W20406).....	291	12368	A	1	.82	20.40	67.86	10.92	3.08	4.34	77.62	1.08	2.96	....	7,630	13,734
				2	....	20.57	68.42	11.01	3.11	4.29	78.26	1.09	2.24	....	7,693	13,847
				3	....	23.11	76.89	....	3.49	4.82	87.94	1.22	2.53	....	8,645	15,561
Morrisdale; Morrisdale No. 1 mine, Middle Kittanning or C bed (face of sump heading, 3,100 feet from shaft No. 1, 5-foot bed, 4-foot 8½-inch cut).	293	12079	A	1	3.47	20.49	67.30	8.74	1.09	....	....	....	....	2.8	7,644	13,759
				2	....	21.23	69.72	9.05	1.13	....	....	....	....	....	7,918	14,252
				3	....	23.34	76.66	....	1.24	....	....	....	....	....	8,706	15,671
Same (at face of McKinley heading, off Truck main heading, 5,850 feet from bottom of shaft No. 1, 4-foot 6-inch bed, 4-foot 5¾-inch cut).	293	12080	A	1	4.19	19.70	67.64	8.47	1.07	....	....	....	....	3.1	7,554	13,597
				2	....	20.56	70.60	8.84	1.12	....	....	....	....	....	7,884	14,191
				3	....	22.55	77.45	....	1.23	....	....	....	....	....	8,649	15,568
Same (composite samples 12079 and 12080)........	293	12082	A	1	3.86	19.79	67.54	8.81	1.08	4.85	77.44	1.29	6.53	3.0	7,565	13,617
				2	....	20.58	70.26	9.16	1.12	4.60	80.55	1.34	3.23	....	7,868	14,162
				3	....	22.65	77.35	....	1.23	5.06	88.67	1.48	3.56	....	8,661	15,590
Morrisdale No. 1 mine, Lower Kittanning or B bed (face of main heading, 5,240 feet from bottom of shaft No. 1, 4-foot ½-inch bed, 3-foot 7½-inch cut).	292	12074	A	1	4.15	20.01	66.83	9.01	3.77	....	....	....	....	3.7	7,526	13,547
				2	....	20.88	69.72	9.40	3.93	....	....	....	....	....	7,852	14,134
				3	....	23.05	76.95	....	4.34	....	....	....	....	....	8,667	15,601
Same (face of room 13, off right heading 8, off main heading, 5,040 feet from bottom of shaft No. 1, 4-foot 3¾-inch bed, 3-foot 9¾-inch cut).	292	12075	A	1	3.24	19.58	69.21	7.97	3.41	....	....	....	....	2.7	7,721	13,898
				2	....	20.24	71.52	8.24	3.52	....	....	....	....	....	7,980	14,364
				3	....	22.06	77.94	....	3.84	....	....	....	....	....	8,697	15,655
Same (face of room 45, off right entry 4, off main heading, 5,200 feet from bottom of shaft No. 1, 4-foot 1¾-inch bed, 3-foot 6¾-inch cut).	292	12081	A	1	3.19	21.88	67.24	7.69	3.06	....	....	....	....	2.7	7,746	13,943
				2	....	22.60	69.46	7.94	3.16	....	....	....	....	....	8,002	14,404
				3	....	24.55	75.45	....	3.43	....	....	....	....	....	8,692	15,646
Same (composite of samples 12074, 12075, and 12081)	293	12090	A	1	3.61	20.86	67.07	8.46	3.38	4.92	77.06	1.28	4.90	3.0	7,679	13,822
				2	....	21.64	69.58	8.78	3.51	4.69	79.95	1.33	1.74	....	7,967	14,341
				3	....	23.72	76.28	....	3.85	5.14	87.65	1.46	1.90	....	8,734	15,721
Morrisdale No. 2 mine, Middle Kittaning or C bed (face of heading 6, 4,500 feet from bottom of shaft No. 2, 4-foot 10½-inch bed, 4-foot 9-inch cut).	293	12072	A	1	3.04	19.42	67.38	10.16	1.00	....	....	....	....	2.3	7,548	13,586
				2	....	20.03	69.49	10.48	1.03	....	....	....	....	....	7,785	.4,013
				3	....	22.38	77.62	....	1.15	....	....	....	....	....	8,697	15,655

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CLEARFIELD COUNTY—continued.																
Morrisdale; Morrisdale No. 2 mine, Middle Kittanning or C bed (room 9, left heading 2, off Lucky strike, 2,200 feet from bottom of shaft No. 2, 4-foot 1-inch bed, 4-foot cut).	293	12073	A	1	2.52	20.73	66.96	9.79	1.74	......	......	......	......	2.0	7,640	13,752
				2	......	21.27	68.69	10.04	1.79	......	......	......	......	......	7,838	14,108
				3	......	23.64	76.36	......	1.99	......	......	......	......	......	8,715	15,683
Same (composite of samples 12072 and 12073)	293	12091	A	1	2.83	20.30	66.91	9.96	1.32	4.67	77.05	1.26	5.75	2.2	7,580	13,644
				2	......	20.89	68.86	10.25	1.36	4.49	79.29	1.29	3.32	......	7,801	14,042
				3	......	23.28	76.72	......	1.52	5.00	88.34	1.44	3.70	......	8,692	15,646
Morrisdale No. 3 mine, Lower Kittaning or B bed (room 5, off left heading 1, off new slope tunnel, 1,400 feet from shaft No. 3, 4-foot 1¼-inch bed, 3-foot 6-inch cut).	292	12076	A	1	3.23	19.68	69.75	7.34	1.99	......	......	......	......	2.6	7,806	14,051
				2	......	20.34	72.07	7.59	2.06	......	......	......	......	......	8,067	14,521
				3	......	22.01	77.99	......	2.23	......	......	......	......	......	8,729	15,712
Same (face of shaft No. 2 heading, off main dip, 5,500 feet from shaft, 3-foot 8-inch bed, 2-foot 11½-inch cut).	292	12077	A	1	3.34	19.23	71.07	6.36	1.71	......	......	......	......	2.8	7,897	14,215
				2	......	19.90	73.52	6.58	1.77	......	......	......	......	......	8,170	14,706
				3	......	21.30	78.70	......	1.89	......	......	......	......	......	8,745	15,741
Same (face of Morrisdale heading, 6,300 feet from shaft, 3-foot 10½-inch bed, 3-foot 2½-inch cut).	292	12078	A	1	3.24	19.78	70.02	6.96	2.03	......	......	......	......	2.7	7,862	14,152
				2	......	20.44	72.37	7.19	2.10	......	......	......	......	......	8,125	14,623
				3	......	22.02	77.98	......	2.26	......	......	......	......	......	8,755	15,759
Same (composite samples 12076, 12077, and 12078)..	293	12092	A	1	3.30	20.13	69.57	7.00	1.91	4.66	79.93	1.36	5.14	2.7	7,862	14,152
				2	......	20.82	71.94	7.24	1.98	4.44	82.66	1.41	2.27	......	8,130	14,634
				3	......	22.45	77.55	......	2.13	4.79	89.12	1.52	2.44	......	8,765	15,777
Munson; Colorado No. 5 mine, Lower Kittaning or B bed (at face of left entry 6, off line heading, 4-foot 1-inch bed, 3-foot cut).	294	12109	A	1	3.74	19.77	69.68	6.81	1.66	......	......	......	......	2.7	7,835	14,108
				2	......	20.54	72.39	7.07	1.72	......	......	......	......	......	8,140	14,652
				3	......	22.10	77.90	......	1.85	......	......	......	......	......	8,759	15,766
Same (face of left entry 8, off main heading, 3,000 feet from drift mouth, 4-foot 2½-inch bed, 3-foot 2-inch cut).	294	12110	A	1	3.58	20.28	69.21	6.93	1.78	......	......	......	......	2.7	7,835	14,103
				2	......	21.03	71.78	7.19	1.85	......	......	......	......	......	8,126	14,627
				3	......	22.66	77.34	......	1.99	......	......	......	......	......	8,756	15,761
Same (face of main heading, 3,600 feet from drift mouth, 4-foot 4½-inch bed, 3-foot 2¾-inch cut).	294	12111	A	1	3.31	20.02	69.34	7.33	1.64	......	......	......	......	2.4	7,817	14,071
				2	......	20.70	71.72	7.58	1.70	......	......	......	......	......	8,084	14,551
				3	......	22.40	77.60	......	1.84	......	......	......	......	......	8,747	15,745
Same (face of line heading, 4-foot 3½-inch bed, 3-foot 2-inch cut).	294	12112	A	1	3.27	19.91	68.31	8.51	2.92	......	......	......	......	2.5	7,688	13,838
				2	......	20.58	70.62	8.80	3.02	......	......	......	......	......	7,948	14,306
				3	......	22.57	77.43	......	3.31	......	......	......	......	......	8,715	15,687

Same (face of left heading 6, off main heading, 4-foot 10¾-inch bed, 3-foot 9¾-inch cut).	294	12113.	A	1	3.40	19.44	68.75	8.41	2.02	......	......	......	......	2.4	7,673	13,811
				2	......	20.12	71.17	8.71	2.09	......	......	......	......	......	7,943	14,297
				3	......	22.04	77.96	......	2.29	......	......	......	......	......	8,701	15,662
Same (composite of samples 12109–12113).........	294	12114	A	1	3.27	19.91	69.02	7.80	2.02	4.84	78.95	1.32	5.07	2.5	7,789	14,020
				2	......	20.58	71.36	8.06	2.09	4.63	81.62	1.36	2.24	......	8,052	14,494
				3	......	22.38	77.62	......	2.27	5.04	88.78	1.48	2.43	......	8,758	15,764
Osceola Mills, 3 miles west of; Fairmount No. 2 mine, Lower Freeport or D bed (face of room 5, off left heading 2, 5-foot 1-inch bed and cut).	294	W17010	A	1	3.1	21.0	69.7	6.2	1.55	......	......	......	......	......	7,861	14,150
				2	......	21.5	72.1	6.4	1.60	......	......	......	......	......	8,117	14,610
				3	......	23.0	77.0	......	1.71	......	......	......	......	......	8,672	15,610
Same (face of room 14, off right heading 8, 5-foot 3½-inch bed and cut).	294	W17012	A	1	2.4	22.5	68.8	6.3	1.00	......	......	......	......	......	7,967	14,340
				2	......	23.0	70.6	6.4	1.00	......	......	......	......	......	8,161	14,690
				3	......	24.6	75.4	......	1.07	......	......	......	......	......	8,717	15,690
Same (composite of samples W17010 and W17012)	295	11711	A	1	1.80	......	......	6.44	1.31	4.71	81.71	1.28	4.55	......	......	......
				2	......	......	......	6.56	1.33	4.50	83.21	1.30	3.01	......	......	......
				3	......	......	......	......	1.42	4.91	89.05	1.39	3.23	......	......	......
Philipsburg, 2 miles west of; Guion mine, Lower Kittanning or B bed (face of right heading 1, off right entry 2, 4,000 feet from mine mouth, 3-foot 1½ inch bed and cut).	295	W20369	A	1	2.0	20.0	69.9	8.1	1.05	......	......	......	......	......	7,828	14,090
				2	......	20.4	71.3	8.3	1.10	......	......	......	......	......	7,983	14,370
				3	......	22.2	77.8	......	1.20	......	......	......	......	......	8,711	15,680
Same (face of right heading 2, 4,000 feet from mine mouth, 3-foot 2-inch bed and cut).	295	W20370	A	1	2.0	21.5	69.2	7.3	1.00	......	......	......	......	......	7,906	14,230
				2	......	21.9	70.7	7.4	1.05	......	......	......	......	......	8,067	14,520
				3	......	23.7	76.3	......	1.13	......	......	......	......	......	8,711	15,680
Same (back heading, off right entry 1, 2,500 feet from mine mouth, 3-foot 4-inch bed, 2-foot 8-inch cut).	295	W20371	A	1	2.9	18.4	69.1	9.6	2.15	......	......	......	......	......	7,600	13,680
				2	......	18.9	71.2	9.9	2.20	......	......	......	......	......	7,828	14,090
				3	......	21.0	79.0	......	2.44	......	......	......	......	......	8,683	15,630
Same (50 feet from face of left heading 1, off right entry 2, 3-foot 5½-inch bed and cut).	295	W20372	A	1	2.0	19.2	70.1	8.7	1.53	......	......	......	......	......	7,789	14,020
				2	......	19.6	71.5	8.9	1.60	......	......	......	......	......	7,950	14,310
				3	......	21.5	78.5	......	1.76	......	......	......	......	......	8,728	15,710
Same (face of left heading 1, off right entry 1, 2,200 feet from mine mouth, 3-foot 6½-inch bed, 3-foot 2¾-inch cut).	295	W20373	A	1	2.4	19.6	67.5	10.5	1.85	......	......	......	......	......	7,539	13,570
				2	......	20.1	69.1	10.8	1.90	......	......	......	......	......	7,728	13,910
				3	......	22.5	77.5	......	2.13	......	......	......	......	......	8,667	15,600
Same (composite of samples W20369–W20373)....	295	12367	A	1	.90	21.59	68.49	9.02	1.99	4.57	79.49	1.31	3.62	......	7,811	14,060
				2	......	21.79	69.11	9.10	2.01	4.51	80.21	1.32	2.85	......	7,882	14,188
				3	......	23.97	76.03	......	2.21	4.96	88.24	1.45	3.14	......	8,671	15,608
Smoke Run, 3½ miles southeast of; Viola mine, Miller or B bed (near face of left heading 9, beyond room 18, 1,300 feet from main haulage way, 5-foot 8-inch bed, 4-foot 10-inch cut).	296	11748	A	1	3.83	20.40	68.87	6.90	1.11	......	......	......	......	3.1	7,812	14,062
				2	......	21.21	71.62	7.17	1.15	......	......	......	......	......	8,123	14,621
				3	......	22.85	77.15	......	1.24	......	......	......	......	......	8,750	15,750
Same (face of second slant to right just beyond room 3, 5-foot ¼-inch bed, 4-foot ¾-inch cut).	296	11749	A	1	3.67	20.36	68.87	7.10	.90	......	......	......	......	2.9	7,822	14,080
				2	......	21.14	71.49	7.37	.93	......	......	......	......	......	8,120	14,616
				3	......	22.82	77.18	......	1.00	......	......	......	......	......	8,766	15,779
Same (face of main entry, 4,750 feet southwest of opening, 5-foot 4½-inch bed, 4-foot 4½-inch cut).	296	11750	A	1	3.67	20.30	67.64	8.39	1.18	......	......	......	......	2.9	7,706	13,871
				2	......	21.07	70.22	8.71	1.22	......	......	......	......	......	8,000	14,400
				3	......	23.08	76.92	......	1.34	......	......	......	......	......	8,763	15,773
Same (composite of samples 11748, 11749, and 11750).	296	11751	A	1	3.73	20.29	68.41	7.57	1.33	4.86	78.92	1.22	6.10	3.0	7,761	13,970
				2	......	21.08	71.06	7.86	1.38	4.62	81.97	1.27	2.90	......	8,061	14,510
				3	......	22.88	77.12	......	1.50	5.01	88.96	1.38	3.15	......	8,749	15,748
Same (near face of left entry 10; 100 feet from room 12; 5-foot 4½-inch bed, 4-foot 5½-inch cut).	296	W18355	A	1	3.0	19.6	70.3	7.1	.75	......	......	......	......	......	7,822	14,080
				2	......	20.2	72.5	7.3	.75	......	......	......	......	......	8,061	14,510
				3	......	21.8	78.2	......	.81	......	......	......	......	......	8,694	15,650

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CLEARFIELD COUNTY—continued.																
Morrisdale: Morrisdale No. 2 mine, Middle Kittanning or C bed (room 9, left heading 2, off Lucky strike, 2,200 feet from bottom of shaft No. 2, 4-foot 1-inch bed, 4-foot cut).	293	12073	A	1	2.52	20.73	66.96	9.79	1.74	......	......	......	......	2.0	7,640	13,752
				2	......	21.27	68.69	10.04	1.79	......	......	......	......	......	7,838	14,108
				3	......	23.64	76.36	......	1.99	......	......	......	......	......	8,715	15,683
Same (composite of samples 12072 and 12073)	293	12091	A	1	2.83	20.30	66.91	9.96	1.32	4.67	77.05	1.25	5.75	2.2	7,580	13,644
				2	......	20.89	68.86	10.25	1.36	4.49	79.29	1.29	3.32	......	7,801	14,042
				3	......	23.28	76.72	......	1.52	5.00	88.34	1.44	3.70	......	8,692	15,646
Morrisdale No. 3 mine, Lower Kittaning or B bed (room 5, off left heading 1, off new slope tunnel, 1,400 feet from shaft No. 3, 4-foot 1¼-inch bed, 3-foot 6-inch cut).	292	12076	A	1	3.23	19.68	69.75	7.34	1.99	......	......	......	......	2.6	7,806	14,051
				2	......	20.34	72.07	7.59	2.06	......	......	......	......	......	8,067	14,521
				3	......	22.01	77.99	......	2.23	......	......	......	......	......	8,729	15,712
Same (face of shaft No. 2 heading, off main dip, 5,500 feet from shaft, 3-foot 8-inch bed, 2-foot 11½-inch cut).	292	12077	A	1	3.34	19.23	71.07	6.36	1.71	......	......	......	......	2.8	7,897	14,215
				2	......	19.90	73.52	6.58	1.77	......	......	......	......	......	8,170	14,706
				3	......	21.30	78.70	......	1.89	......	......	......	......	......	8,745	15,741
Same (face of Morrisdale heading, 6,300 feet from shaft, 3-foot 10½-inch bed, 3-foot 2½-inch cut).	292	12078	A	1	3.24	19.78	70.02	6.96	2.03	......	......	......	......	2.7	7,862	14,152
				2	......	20.44	72.37	7.19	2.10	......	......	......	......	......	8,125	14,623
				3	......	22.02	77.98	......	2.26	......	......	......	......	......	8,755	15,759
Same (composite samples 12076, 12077, and 12078)..	293	12092	A	1	3.30	20.13	69.57	7.00	1.91	4.66	79.93	1.36	5.14	2.7	7,862	14,152
				2	......	20.82	71.94	7.24	1.98	4.44	82.66	1.41	2.27	......	8,130	14,634
				3	......	22.45	77.55	......	2.13	4.79	89.12	1.52	2.44	......	8,765	15,777
Munson: Colorado No. 5 mine, Lower Kittaning or B bed (at face of left entry 6, off line heading, 4-foot 1-inch bed, 3-foot cut).	294	12109	A	1	3.74	19.77	69.68	6.81	1.66	......	......	......	......	2.7	7,835	14,108
				2	......	20.54	72.39	7.07	1.72	......	......	......	......	......	8,140	14,652
				3	......	22.10	77.90	......	1.85	......	......	......	......	......	8,759	15,766
Same (face of left entry 8, off main heading, 3,000 feet from drift mouth, 4-foot 2½-inch bed, 3-foot 2-inch cut).	294	12110	A	1	3.58	20.28	69.21	6.93	1.78	......	......	......	......	2.7	7,835	14,103
				2	......	21.03	71.78	7.19	1.85	......	......	......	......	......	8,126	14,627
				3	......	22.66	77.34	......	1.99	......	......	......	......	......	8,756	15,761
Same (face of main heading, 3,600 feet from drift mouth, 4-foot 4½-inch bed, 3-foot 2¾-inch cut).	294	12111	A	1	3.31	20.02	69.34	7.33	1.64	......	......	......	......	2.4	7,817	14,071
				2	......	20.70	71.72	7.58	1.70	......	......	......	......	......	8,084	14,551
				3	......	22.40	77.60	......	1.84	......	......	......	......	......	8,747	15,745
Same (face of line heading, 4-foot 3½-inch bed, 3-foot 2-inch cut).	294	12112	A	1	3.27	19.91	68.31	8.51	2.92	......	......	......	......	2.5	7,688	13,838
				2	......	20.58	70.62	8.80	3.02	......	......	......	......	......	7,948	14,306
				3	......	22.57	77.43	......	3.31	......	......	......	......	......	8,715	15,687

Same (face of third south or up-creek heading, 4-foot 6¾-inch bed, 3 foot 7½-inch cut).	298	12122	A	1	1.98	13.38	79.26	5.38	.86	....	....	....	....	1.3	8,159	14,686
				2	....	13.65	80.86	5.49	.88	....	....	....	....	....	8,324	14,982
				3	....	14.44	85.56	....	.92	....	....	....	....	....	8,808	15,854
Same (face of second west tunnel 4-foot 9⅜-inch bed, 3-foot 11¾-inch cut).	298	12123	A	1	1.85	14.14	78.09	5.92	.92	....	....	....	....	1.3	8,116	14,609
				2	....	14.41	79.56	6.03	1.00	....	....	....	....	....	8.269	14,884
				3	....	15.34	84.66	....	1.06	....	....	....	....	....	8,800	15,840
Same (No. 7 or Bolinger heading, 5-foot 10⅜-inch bed, 5-foot 1⅜-inch cut).	298	12124	A	1	2.43	15.31	75.48	6.78	1.79	....	....	....	....	1.7	7,939	14,290
				2	....	15.69	77.36	6.95	1.83	....	....	....	....	....	8,137	14,647
				3	....	16.86	83.14	....	1.97	....	....	....	....	....	8,745	15,741
Same (composite of samples 12121–12124).........	298	12125	A	1	2.18	14.07	77.62	6.13	1.14	4.46	83.33	1.30	3.64	1.6	8,085	14,553
				2	....	14.38	79.35	6.27	1.17	4.31	85.19	1.33	1.73	....	8,265	14,877
				3	....	15.34	84.66	....	1.26	4.60	90.89	1.42	1,84	....	8.18	15,872
INDIANA COUNTY.																
Clymer, 1½ miles north of; Empire M (McKean) mine; Lower Kittanning or B bed; corner of pillar of room 44, off right entry 1, off main entry, 3-foot 3½-inch cut).	299	W19682	A	1	2.2	26.4	64.6	6.8	1.95	....	....	....	....	....	7,956	14,320
				2	....	27.0	66.0	7.0	2.00	....	....	....	....	....	8,133	14,640
				3	....	29.0	71.0	....	2.15	....	....	....	....	....	8,744	15,740
Same (face of room 56, off right entry 2, off main entry, 4,000 feet east of mine mouth, 3-foot 2½-inch bed and cut).	299	W19678	A	1	1.9	26.5	64.0	7.6	2.40	....	....	....	....	....	7,911	14,240
				2	....	27.0	65.2	7.8	2.50	....	....	....	....	....	8,061	14,510
				3	....	29.3	70.7	....	2.71	....	....	....	....	....	8,744	15,740
Same (corner of crosscut at room 40, off right entry 2, off main entry, 3,000 feet southeast of mine mouth, 3-foot 2½-inch cut).	299	W19680	A	1	2.1	26.5	63.4	8.0	2.25	....	....	....	....	....	7,811	14,060
				2	....	27.1	64.7	8.2	2.30	....	....	....	....	....	7,978	14,360
				3	....	29.5	70.5	....	2.51	....	....	....	....	....	8,694	15,650
Same (face of first parallel, off south heading, off right entry 1, off main entry, 2,800 feet southwest of mine mouth, 3-foot 5½-inch cut).	299	W19685	A	1	2.8	26.4	64.4	6.4	1.65	....	....	....	....	....	7,917	14,250
				2	....	27.2	66.2	6.6	1.70	....	....	....	....	....	8,150	14,670
				3	....	29.1	70.9	....	1.82	....	....	....	....	....	8,728	15,710
Same (face of third parallel, off south heading, off right entry 1, off main entry, 3-foot 3⅜-inch cut).	299	W19687	A	1	2.5	26.9	63.9	6.7	1.70	....	....	....	....	....	7,917	14,250
				2	....	27.6	65.5	6.9	1.75	....	....	....	....	....	8,122	14,620
				3	....	29.6	70.4	....	1.88	....	....	....	....	....	8,722	15,700
Same (composite of samples W19678, W19680, W19685, and W19687).	299	12223	A	1	1.30	26.70	64.40	7.60	2.03	5.02	80.35	1.36	3.64	....	7,953	14,315
				2	....	27.05	65.26	7.70	2.06	4.94	81.41	1.38	2.51	....	8,058	14,504
				3	....	29.31	70.69	....	2.23	5.35	88.20	1.50	2.72	....	8,730	15,714
1 mile north of; Empire R mine, Lower Kittanning or B bed (pillar at room 28, in left entry 2, off main entry, 2,200 feet east of mine mouth, 3-foot 2-inch bed and cut).	300	W19681	A	1	2.1	26.5	64.9	6.5	1.70	....	....	....	....	....	7,972	14,350
				2	....	27.1	66.3	6.6	1.75	....	....	....	....	....	8,139	14,650
				3	....	29.0	71.0	....	1.87	....	....	....	....	....	8,717	15,690
Same (crosscut at corner of room 47, off left entry 1, off main entry, 4,700 feet southeast of mine mouth, 3-foot 2½-inch bed, 3-foot 1⅜-inch cut).	300	W19679	A	1	2.3	26.6	63.3	7.8	2.70	....	....	....	....	....	7,839	14,110
				2	....	27.2	64.8	8.0	2.75	....	....	....	....	....	8,022	14,440
				3	....	29.6	70.4	....	2.99	....	....	....	....	....	8,722	15,700
Same (face of room 3, off right entry 1, off main entry, 1,100 feet south of mine mouth, 3-foot 10¾-inch bed and cut).	300	W19683	A	1	2.0	26.6	64.4	7.0	1.90	....	....	....	....	....	7,961	14,330
				2	....	27.1	65.8	7.1	1.95	....	....	....	....	....	8,122	14,620
				3	....	29.2	70.8	....	2.10	....	....	....	....	....	8,750	5,750
Same (face of room 11, left entry 5, off main entry, 1,900 feet southeast of mine mouth, 3-foot 2⅜-inch bed and cut).	300	W19684	A	1	2.2	26.0	64.5	7.3	2.15	....	....	....	....	....	7,850	14,130
				2	....	26.6	65.9	7.5	2.20	....	....	....	....	....	8,022	14,440
				3	....	28.8	71.2	....	2.38	....	....	....	....	....	8,672	15,610
Same (near face of room 43, off left entry 4, off main entry, 3,100 feet from mine mouth, 3-foot 2½-inch bed and cut).	300	W19686	A	1	1.9	26.6	64.7	6.8	2.15	....	....	....	....	....	7,972	14,350
				2	....	27.1	66.0	6.9	2.20	....	....	....	....	....	8,128	14,630
				3	....	29.1	70.9	....	2.36	....	....	....	....	....	8,728	15,710
Same (composite of samples W19679, W19683, W19684, and W19686).	300	12219	A	1	1.23	26.37	64.84	7.56	2.41	4.99	79.89	1.37	3.78	....	7,943	14,297
				2	....	26.70	65.65	7.65	2.44	4.91	80.89	1.39	2.72	....	8,042	14,476
				3	....	28.91	71.09	....	2.64	5.32	87.59	1.51	2.94	....	8,708	15,674

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
CLEARFIELD COUNTY—continued.																
Smoke Run, 3½ miles southeast of; Viola Mine, Miller or B bed (near face of third slant entry, 100 feet above room 1, 5-foot bed, 4 foot 11-inch cut).	296	W18356	A	1	3.0	19.2	69.7	8.1	1.60	......	......	......	......	......	7,767	13,980
				2	......	19.8	71.8	8.4	1.65	......	......	......	......	......	8,006	14,410
				3	......	21.6	78.4	......	1.80	......	......	......	......	......	8,739	15,730
Same (near face of left heading 9, 5-foot 7⅝-inch bed, 4-foot 7⅝-inch cut).	296	W18357	A	1	3.4	19.5	70.4	6.7	1.00	......	......	......	......	......	7,867	14,160
				2	......	20.2	72.9	6.9	1.05	......	......	......	......	......	8,144	14,660
				3	......	21.7	78.3	......	1.13	......	......	......	......	......	8,750	15,750
Same (face of main entry, 4,800 feet southwest of opening, 5-foot 1⅜-inch bed, 4-foot 10⅜-inch cut).	296	W18358	A	1	3.3	19.0	69.7	8.0	1.60	......	......	......	......	......	7,711	13,880
				2	......	19.7	72.0	8.3	1.65	......	......	......	......	......	7,978	14,360
				3	......	21.5	78.5	......	1.80	......	......	......	......	......	8,700	15,660
Same (face of second slant entry, 100 feet above third slant entry, 5-foot bed, 4-foot 1-inch cut).	296	W18359	A	1	3.3	19.0	70.2	7.5	1.00	......	......	......	......	......	7,833	14,100
				2	......	19.6	72.6	7.8	1.05	......	......	......	......	......	8,094	14,570
				3	......	21.3	78.7	......	1.14	......	......	......	......	......	8,778	15,800
HUNTINGDON COUNTY.																
Robertsdale, Robertsdale mine; Fulton (Lower Kittanning or B) bed (face of north heading 6, 6-foot 3⅛-inch bed, 4-foot 5⅜-inch cut).	297	12115	A	1	2.26	14.81	76.54	6.39	1.36	......	......	......	......	1.6	8,038	14,468
				2	......	15.15	78.31	6.54	1.39	......	......	......	......	......	8,224	14,803
				3	......	16.21	83.79	......	1.49	......	......	......	......	......	8,800	15,840
Same (at face of main west heading, 5-foot 4-inch bed, 3-foot 9-inch cut).	297	12116	A	1	1.92	15.23	77.25	5.60	.80	......	......	......	......	1.2	8,130	14,634
				2	......	15.53	78.76	5.71	.82	......	......	......	......	......	8,289	14,920
				3	......	16.47	83.53	......	.87	......	......	......	......	......	8,791	15,824
Same (at face of south heading 6, 6-foot 1¼-inch bed, 4-foot 9¼-inch cut).	297	12117	A	1	1.95	14.58	76.24	7.23	.94	......	......	......	......	1.3	7,983	14,369
				2	......	14.87	77.76	7.37	.96	......	......	......	......	......	8,142	14,656
				3	......	16.05	83.95	......	1.04	......	......	......	......	......	8,790	15,822
Same (face of south heading 8, 5-foot 3-inch bed, 4-foot 3-inch cut).	297	12118	A	1	2.20	13.93	77.44	6.43	1.08	......	......	......	......	1.5	8,046	14,483
				2	......	14.24	79.19	6.57	1.10	......	......	......	......	......	8,227	14,809
				3	......	15.24	84.76	......	1.18	......	......	......	......	......	8,805	15,849
Same (face of south heading 5, 3-foot 11⅝-inch bed, 3-foot 4⅝-inch cut).	297	12119	A	1	2.34	15.64	75.55	6.47	1.02	......	......	......	......	1.7	8,008	14,414
				2	......	16.02	77.35	6.63	1.04	......	......	......	......	......	8,200	14,760
				3	......	17.16	82.84	......	1.11	......	......	......	......	......	8,782	15,808
Same (composite of samples 12115–12119).........	298	12120	A	1	2.14	15.47	75.96	6.43	1.05	4.44	82.83	1.27	3.98	1.5	8,039	14,470
				2	......	15.81	77.62	6.57	1.07	4.29	84.64	1.30	2.13	......	8,215	14,787
				3	......	16.92	83.08	......	1.15	4.59	90.59	1.39	2.28	......	8,793	15,827
Woodvale; Woodvale mine, Fulton (Lower Kittanning or B) bed (face of south heading 1, 4-foot 5⅝-inch bed, 3-foot 9⅝-inch cut).	298	12121	A	1	2.92	14.28	76.74	6.06	.94	......	......	......	......	2.2	7,997	14,395
				2	......	14.71	79.05	6.24	.97	......	......	......	......	......	8,238	14,828
				3	......	15.69	84.31	......	1.03	......	......	......	......	......	8,787	15,817

Same (face of third south or up-creek heading, 4-foot 6¼-inch bed, 3 foot 7¼-inch cut).	298	12122	A	1	1.98	13.38	79.26	5.38	.86	......	......	......	......	1.3	8,159	14,686
				2	......	13.65	80.86	5.49	.88	......	......	......	......	......	8,324	14,982
				3	......	14.44	85.56	......	.92	......	......	......	......	......	8,808	15,854
Same (face of second west tunnel 4-foot 9½-inch bed, 3-foot 11¾-inch cut).	298	12123	A	1	1.85	14.14	78.09	5.92	.92	......	......	......	......	1.3	8,116	14,609
				2	......	14.41	79.56	6.03	1.00	......	......	......	......	......	8.269	14,884
				3	......	15.34	84.66	......	1.06	......	......	......	......	......	8,800	15,840
Same (No. 7 or Bolinger heading, 5-foot 10½-inch bed, 5-foot 1½-inch cut).	298	12124	A	1	2.43	15.31	75.48	6.78	1.79	......	......	......	......	1.7	7,939	14,290
				2	......	15.69	77.36	6.95	1.83	......	......	......	......	......	8,137	14,647
				3	......	16.86	83.14	......	1.97	......	......	......	......	......	8,745	15,741
Same (composite of samples 12121–12124).........	298	12125	A	1	2.18	14.07	77.62	6.13	1.14	4.46	83.33	1.30	3.64	1.6	8,085	14,553
				2	......	14.38	79.35	6.27	1.17	4.31	85.19	1.33	1.73	......	8,265	14,877
				3	......	15.34	84.66	......	1.26	4.60	90.89	1.42	1,84	......	8.18	15,872
INDIANA COUNTY.																
Clymer, 1¼ miles north of; Empire M (McKean) mine; Lower Kittanning or B bed; corner of pillar of room 44, off right entry 1, off main entry, 3-foot 3¼-inch cut).	299	W19682	A	1	2.2	26.4	64.6	6.8	1.95	......	......	......	......	......	7,956	14,320
				2	......	27.0	66.0	7.0	2.00	......	......	......	......	......	8,133	14,640
				3	......	29.0	71.0	......	2.15	......	......	......	......	......	8,744	15,740
Same (face of room 56, off right entry 2, off main entry, 4,000 feet east of mine mouth, 3-foot 2¾-inch bed and cut).	299	W19678	A	1	1.9	26.5	64.0	7.6	2.40	......	......	......	......	......	7,911	14,240
				2	......	27.0	65.2	7.8	2.50	......	......	......	......	......	8,061	14,510
				3	......	29.3	70.7	......	2.71	......	......	......	......	......	8,744	15,740
Same (corner of crosscut at room 40, off right entry 2, off main entry, 3,000 feet southeast of mine mouth, 3-foot 2¼-inch cut).	299	W19680	A	1	2.1	26.5	63.4	8.0	2.25	......	......	......	......	......	7,811	14,060
				2	......	27.1	64.7	8.2	2.30	......	......	......	......	......	7,978	14,360
				3	......	29.5	70.5	......	2.51	......	......	......	......	......	8,694	15,650
Same (face of first parallel, off south heading, off right entry 1, off main entry, 2,800 feet southwest of mine mouth, 3-foot 5¼-inch cut).	299	W19685	A	1	2.8	26.4	64.4	6.4	1.65	......	......	......	......	......	7,917	14,250
				2	......	27.2	66.2	6.6	1.70	......	......	......	......	......	8,150	14,670
				3	......	29.1	70.9	......	1.82	......	......	......	......	......	8,728	15,710
Same (face of third parallel, off south heading, off right entry 1, off main entry, 3-foot 3¼-inch cut).	299	W19687	A	1	2.5	26.9	63.9	6.7	1.70	......	......	......	......	......	7,917	14,250
				2	......	27.6	65.5	6.9	1.75	......	......	......	......	......	8,122	14,620
				3	......	29.6	70.4	......	1.88	......	......	......	......	......	8,722	15,700
Same (composite of samples W19678, W19680, W19685, and W19687).	299	12223	A	1	1.30	26.70	64.40	7.60	2.03	5.02	80.35	1.36	3.64	......	7,953	14,315
				2	......	27.05	65.26	7.70	2.06	4.94	81.41	1.38	2.51	......	8,058	14,504
				3	......	29.31	70.69	......	2.23	5.35	88.20	1.50	2.72	......	8,730	15,714
1 mile north of; Empire R mine, Lower Kittanning or B bed (pillar at room 28, in left entry 2, off main entry, 2,200 feet east of mine mouth, 3-foot 2-inch bed and cut).	300	W19681	A	1	2.1	26.5	64.9	6.5	1.70	......	......	......	......	......	7,972	14,350
				2	......	27.1	66.3	6.6	1.75	......	......	......	......	......	8,139	14,650
				3	......	29.0	71.0	......	1.87	......	......	......	......	......	8,717	15,690
Same (crosscut at corner of room 47, off left entry 1, off main entry, 4,700 feet southeast of mine mouth, 3-foot 2¼-inch bed, 3-foot 1⅝-inch cut).	300	W19679	A	1	2.3	26.6	63.3	7.8	2.70	......	......	......	......	......	7,839	14,110
				2	......	27.2	64.8	8.0	2.75	......	......	......	......	......	8,022	14,440
				3	......	29.6	70.4	......	2.99	......	......	......	......	......	8,722	15,700
Same (face of room 3, off right entry 1, off main entry, 1,100 feet south of mine mouth, 3-foot 10⅞-inch bed and cut).	300	W19683	A	1	2.0	26.6	64.4	7.0	1.90	......	......	......	......	......	7,961	14,330
				2	......	27.1	65.8	7.1	1.95	......	......	......	......	......	8,122	14,620
				3	......	29.2	70.8	......	2.10	......	......	......	......	......	8,750	5,750
Same (face of room 11, left entry 5, off main entry, 1,900 feet southeast of mine mouth, 3-foot 2⅝-inch bed and cut).	300	W19684	A	1	2.2	26.0	64.5	7.3	2.15	......	......	......	......	......	7,850	14,130
				2	......	26.6	65.9	7.5	2.20	......	......	......	......	......	8,022	14,440
				3	......	28.8	71.2	......	2.38	......	......	......	......	......	8,672	15,610
Same (near face of room 43, off left entry 4, off main entry, 3,100 feet from mine mouth, 3-foot 2½-inch bed and cut).	300	W19686	A	1	1.9	26.6	64.7	6.8	2.15	......	......	......	......	......	7,972	14,350
				2	......	27.1	66.0	6.9	2.20	......	......	......	......	......	8,128	14,630
				3	......	29.1	70.9	......	2.36	......	......	......	......	......	8,728	15,710
Same (composite of samples W19679, W19683, W19684, and W19686).	300	12219	A	1	1.23	26.37	64.84	7.56	2.41	4.99	79.89	1.37	3.78	......	7,943	14,297
				2	......	26.70	65.65	7.65	2.44	4.91	80.89	1.39	2.72	......	8,042	14,476
				3	......	28.91	71.09	......	2.64	5.32	87.59	1.51	2.94	......	8,708	15,674

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
INDIANA COUNTY—continued.																
Glen Campbell, 2½ miles north of Huvershurst Junction; Indiana No. 6 mine, Upper Freeport or E bed (face of left heading 7, off main entry, 3,000 feet northwest of mine mouth, 4-foot 3¾-inch bed, 3-foot 8¼-inch cut).	301	12102	A	1	3.01	27.42	61.30	8.27	1.30	....	....	....	....	1.8	7,650	13,770
				2	....	28.27	63.20	8.53	1.34	....	....	....	....	....	7,887	14,197
				3	....	30.91	69.09	....	1.47	....	....	....	....	....	8,623	15,521
Same (face of room 10 off left entry 1, off main heading, 1,000 feet northeast of mine mouth, 4-foot 10¾-inch bed, 3-foot 10½-inch cut).	301	12103	A	1	2.89	26.89	61.69	8.53	1.20	....	....	....	....	1.7	7,622	13,720
				2	....	27.69	63.53	8.78	1.23	....	....	....	....	....	7,849	14,128
				3	....	30.36	69.64	....	1.35	....	....	....	....	....	8,606	15,491
Same (rib near face of room 14, in right heading 7, off main entry, 2,000 feet northwest of mine mouth, 4-foot 11¾-inch bed, 4-foot 1⅛-inch cut).	301	12104	A	1	3.66	26.95	61.24	8.15	1.19	....	....	....	....	2.5	7,611	13,700
				2	....	27.97	63.57	8.46	1.24	....	....	....	....	....	7,900	14,220
				3	....	30.55	69.45	....	1.35	....	....	....	....	....	8,630	15,534
Same (face of left heading 6, off main entry, 2,200 feet southwest of mine mouth, 4-foot 8¾-inch bed, 3-foot 11-inch cut).	301	12105	A	1	2.88	27.93	60.25	8.94	1.70	....	....	....	....	1.7	7,610	13,698
				2	....	28.76	62.03	9.21	1.75	....	....	....	....	....	7,836	14,105
				3	....	31.68	68.32	....	1.93	....	....	....	....	....	8,631	15,536
Same (near face of room 1, on right heading 8, off main entry, 2,300 feet northwest of mine mouth, 4-foot 10¼-inch bed, 4-foot ⅜-inch cut).	301	12166	A	1	3.23	27.44	61.05	8.28	1.26	....	....	....	....	1.9	7,609	13,696
				2	....	28.36	63.08	8.56	1.30	....	....	....	....	....	7,863	14,153
				3	....	31.01	68.99	....	1.42	....	....	....	....	....	8,599	15,478
Same (composite of samples 12102–12106).........	301	12107	A	1	3.08	27.32	61.16	8.44	1.29	4.99	76.71	1.27	7.30	1.9	7,651	13,772
				2	....	28.19	63.10	8.71	1.33	4.80	79.15	1.31	4.70	....	7,894	14,209
				3	....	30.88	69.12	....	1.46	5.26	86.70	1.43	5.15	....	8,647	15,565
Homer City, 1 mile northwest of; Tearing Run mine, E or Upper Freeport bed (No. 4 stump, on right entry 1, off main entry, 5-foot 2¼-inch cut).	301	W20431	A	1	2.6	24.5	64.8	8.1	2.50	....	....	....	....	....	7,739	13,930
				2	....	25.2	66.5	8.3	2.55	....	....	....	....	....	7,944	14,300
				3	....	27.5	72.5	....	2.78	....	....	....	....	....	8,756	15,760
Same (rib of room 10, off left entry 1, off main entry, 3-foot 7½-inch cut).	301	W20428	A	1	2.6	26.5	61.7	9.2	2.80	....	....	....	....	....	7,622	13,720
				2	....	27.2	63.4	9.4	2.90	....	....	....	....	....	7,828	14,090
				3	....	30.0	70.0	....	3.20	....	....	....	....	....	8,639	15,550
Same (face of right entry 2, off main entry, 5-foot 1-inch cut).	301	W20429	A	1	2.8	23.8	64.1	9.3	2.65	....	....	....	....	....	7,550	13,590
				2	....	24.5	65.9	9.6	2.75	....	....	....	....	....	7,767	13,980
				3	....	27.1	72.9	....	3.04	....	....	....	....	....	8,589	15,460

Same (rib near face of left entry 2, off main entry, 5-foot 1½-inch cut).	301	W20430	A	1	2.3	24.6	64.6	8.5	2.20	....	....	....	....	....	7,728	13,910
				2	....	25.2	66.1	8.7	2.25	....	....	....	....	....	7,911	14,240
				3	....	27.6	72.4	....	2.46	....	....	....	....	....	8,667	15,600
Same ("shoo-fly," 100 feet below left entry 3, off main entry, 5-foot 3½-inch cut).	301	W20432	A	1	2.0	24.4	65.2	8.4	2.15	....	....	....	....	....	7,711	13,880
				2	....	24.9	66.5	8.6	2.20	....	....	....	....	....	7,872	14,170
				3	....	27.2	72.8	....	2.41	....	....	....	....	....	8,611	15,500
Same (composite of samples 20428, 20429, 20430, and 20432).	301	12373	A	1	1.00	26.07	63.79	9.14	2.69	4.67	78.12	1.12	4.26	....	7,747	13,945
				2	....	26.33	64.44	9.23	2.72	4.61	78.91	1.13	3.40	....	7,825	14,085
				3	....	29.01	70.99	....	3.00	5.08	86.94	1.24	3.74	....	8,621	15,518
JEFFERSON COUNTY.																
Sykesville, 1 mile south of; Sykesville mine, D or Lower Freeport bed (pillar at last cut-through between eighth left main and the back heading, off main south heading, 5-foot 10½-inch bed, 5-foot 9-inch cut).	302	12455	A	1	2.44	28.44	60.68	8.44	1.82	5.07	76.91	1.31	6.95	1.6	7,629	13,732
				2	....	29.15	62.20	8.65	1.35	4.92	78.83	1.34	4.91	....	7,820	14,076
				3	....	31.91	68.09	....	1.48	5.39	86.30	1.47	5.36	....	8,561	15,410
Same (from cavity in roof between third right butt heading and second back heading in eighth main off main south heading; 6-foot ½-inch bed, 3-foot 7-inch cut).	303	12457	A	1	2.05	28.44	53.51	16.00	4.01	4.65	68.85	1.16	5.33	1.3	6,890	12,402
				2	....	29.03	54.64	16.33	4.09	4.51	70.29	1.18	3.60	....	7,034	12,661
				3	....	34.70	65.30	....	4.89	5.39	84.01	1.41	4.30	....	8,407	15,133
Same (face of third right butt heading off eighth left, off main south heading, 5-foot 8½-inch bed, 5-foot 7-inch cut).	302	12458	A	1	2.53	29.50	60.48	7.49	1.31	5.07	78.06	1.38	6.69	1.5	7,684	13,831
				2	....	30.27	62.05	7.68	1.34	4.91	80.09	1.42	4.56	....	7,884	14,191
				3	....	32.79	67.21	....	1.45	5.32	86.75	1.54	4.94	....	8,540	15,372
Same (cavity in roof of third right butt heading off eighth left main, about 200 feet from face of main heading, 2-foot 7½-inch cut).	303	12471	A	1	1.94	29.01	51.36	17.69	2.28	4.52	67.80	1.15	6.56	1.2	6,721	12,098
				2	....	29.58	52.38	18.04	2.33	4.39	69.14	1.17	4.98	....	6,854	12,337
				3	....	36.09	63.91	....	2.84	5.36	84.36	1.43	6.01	....	8,363	15,053
LACKAWANNA COUNTY.																
Dunmore, 3 miles east of Scranton; Sloan mine, Dunmore No. 2 bed (7-foot cut).	303	11440	B	1	3.43	6.79	78.25	11.53	.46	2.52	78.85	.77	5.87	2.5	7,101	12,782
				2	....	7.03	81.03	11.94	.48	2.22	81.65	.80	2.91	....	7,353	13,235
				3	....	7.98	92.02	....	.55	2.52	92.72	.91	3.30	....	8,350	15,030
LUZERNE COUNTY.																
Pittston, 2 miles southwest of; Colliery No. 14 mine, Pittston bed (working face of rear station 4695, on Brannagan slope).	303	11441	B	1	2.19	5.67	86.24	5.90	.57	2.70	86.37	.91	3.55	1.6	7,682	13,828
				2	....	5.80	88.17	6.03	.58	2.52	88.30	.93	1.64	....	7,854	14,137
				3	....	6.17	93.83	....	.62	2.68	93.97	.99	1.74	....	8,358	15,044
Wilkes-Barre, near; Dorrance mine, Red Ash bed (end of first west gangway, 600 feet northwest of shaft).	303	11782	B	1	1.31	5.68	85.87	7.14	.42	2.35	86.76	.68	2.65	.3	7,654	13,777
				2	....	5.76	87.01	7.23	.43	2.23	87.91	.69	1.51	....	7,756	13,961
				3	....	6.21	93.79	....	.46	2.40	94.76	.74	1.64	....	8,360	15,048
SOMERSET COUNTY.																
Acosta, ½ mile north of; Belmont No. 1 mine, Upper Kittanning or C′ bed (face of room 4 off main heading, 1,300 feet from mine mouth, 3-foot 6-inch bed, 3-foot 4½-inch cut).	304	W19536	A	1	2.0	16.1	72.8	9.1	1.35	....	....	....	....	....	7,778	14,000
				2	....	16.4	74.3	9.3	1.40	....	....	....	....	....	7,939	14,290
				3	....	18.1	81.9	....	1.54	....	....	....	....	....	8,756	15,760
Same (face of third left entry, 60 feet from main entry, 3-foot 5½-inch bed, 3-foot 4½-inch cut).	304	W19537	A	1	2.2	15.7	73.4	8.7	1.25	....	....	....	....	....	7,811	14,060
				2	....	16.1	75.0	8.9	1.30	....	....	....	....	....	7,983	14,370
				3	....	17.7	82.3	....	1.43	....	....	....	....	....	8,756	15,760
Same (face of room 3, off first right entry, 3-foot 9½-inch bed and cut).	304	W19538	A	1	2.0	15.5	72.7	9.8	1.60	....	....	....	....	....	7,683	13,830
				2	....	15.8	74.2	10.0	1.65	....	....	....	....	....	7,844	14,120
				3	....	17.6	82.4	....	1.83	....	....	....	....	....	8,711	15,680

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
SOMERSET COUNTY—continued.																
Acosta, ½ mile north of; Belmont No. 1 mine, Upper Kittanning or C′ bed (face of left entry 2; 250 feet from main entry; 3-foot 3½-inch bed and cut).	304	W19539	A	1	2.0	16.2	73.1	8.7	1.30	......	......	......	......	......	7,828	14,090
				2	......	16.5	74.6	8.9	1.35	......	......	......	......	......	7,989	14,380
				3	......	18.1	81.9	......	1.48	......	......	......	......	......	8,767	15,780
Same (face of main heading; 1,550 feet from mine mouth, 150 feet above left entry 3; 3-foot 2½-inch bed, 3-foot 1-inch cut).	304	W19543	A	1	1.4	16.4	73.7	8.5	1.05	......	......	......	......	......	7,872	14,170
				2	......	16.6	74.8	8.6	1.10	......	......	......	......	......	7,983	14,370
				3	......	18.2	81.8	......	1.20	......	......	......	......	......	8,733	15,720
Same (composite of samples W19536, W19537, W19538, W19539, and W19543).	304	12209	A	1	1.2	15.65	74.18	8.97	1.39	4.31	80.74	1.36	3.23	......	7,831	14,096
				2	......	15.84	75.08	9.08	1.41	4.23	81.72	1.38	2.18	......	7,926	14,267
				3	......	17.42	82.58	......	1.55	4.65	89.88	1.52	2.40	......	8,718	15,692
Berlin, 1½ miles east of; Coronet No. 3 mine, "Smokeless" or Upper Freeport bed (pillar between rooms 2 and 3 off main air course, between right entries 3 and 4; 1,400 feet from mine mouth).	305	W19535	A	1	3.0	17.7	68.6	10.7	1.50	......	......	......	......	......	7,467	13,440
				2	......	18.2	70.8	11.0	1.55	......	......	......	......	......	7,700	13,860
				3	......	20.4	79.6	......	1.74	......	......	......	......	......	8,656	15,580
Same (face of left entry 8, 15 feet beyond room 15; 2,950 feet from mouth of main entry, 3-foot 9½-inch bed and cut).	305	W19532	A	1	2.3	18.5	66.4	12.8	1.80	......	......	......	......	......	7,406	13,330
				2	......	18.9	68.0	13.1	1.85	......	......	......	......	......	7,583	13,650
				3	......	21.7	78.3	......	2.13	......	......	......	......	......	8,728	15,710
Same (face of right entry 6; 125 feet from main heading, 2,500 feet from mouth of main entry; 3-foot 5½-inch bed, 3-foot 4¾-inch cut).	305	W19533	A	1	2.3	18.4	68.4	10.9	1.35	......	......	......	......	......	7,561	13,610
				2	......	18.8	70.0	11.2	1.40	......	......	......	......	......	7,739	13,930
				3	......	21.2	78.8	......	1.58	......	......	......	......	......	8,711	15,680
Same (face of room 13, off left entry 7, 2,450 feet from mouth of main entry, 3-foot 6½-inch bed, 3-foot 5-inch cut).	305	W19534	A	1	2.4	18.0	68.3	11.3	1.90	......	......	......	......	......	7,522	13,540
				2	......	18.4	70.0	11.6	1.95	......	......	......	......	......	7,706	13,870
				3	......	20.8	79.2	......	2.21	......	......	......	......	......	8,717	15,690
Same (face of right entry 7, 50 feet beyond room 8; 2,800 feet from mouth of main entry, 3-foot 8-inch bed, 3-foot 4½-inch cut).	305	W19542	A	1	2.4	19.0	67.6	11.0	1.90	......	......	......	......	......	7,600	13,680
				2	......	19.5	69.2	11.3	1.95	......	......	......	......	......	7,789	14,020
				3	......	22.0	78.0	......	2.20	......	......	......	......	......	8,783	15,810
Same (composite of samples W19542, W19533, W19532, and W19534).	305	12214	A	1	1.44	18.56	68.44	11.56	1.88	4.39	77.31	1.64	3.22	......	7,558	13,604
				2	......	18.83	69.44	11.73	1.91	4.29	78.44	1.66	1.97	......	7,668	13,802
				3	......	21.33	78.67	......	2.16	4.86	88.86	1.88	2.24	......	8,687	15,637
Confluence, 4½ miles southeast of; Linmer mine, C′ bed (at end of back subentry, off main entry 1, about 2,500 feet southeast of mine mouth, 3-foot 6½-inch bed and cut).	306	13631	B	1	2.8	25.94	63.06	8.20	2.35	......	......	......	......	2.2	7,715	13,887
				2	......	26.69	64.87	8.44	2.42	......	......	......	......	......	7,937	14,287
				3	......	29.15	70.85	......	2.64	......	......	......	......	......	8,669	15,604

Elklick, 2½ miles east of; Eagle mine, D (?) bed (room in mine, about 600 feet east of mine mouth, 3-foot 1½-inch bed, 2-foot 10½-inch cut).	306	13983	B	1	3.49	18.21	69.67	8.63	1.53	....	....	....	....	2.6	7,593	13,667
				2	....	18.87	72.19	8.94	1.59	....	....	....	....	....	7,868	14,162
				3	....	20.72	79.28	....	1.75	....	....	....	....	....	8,641	15,554
2½ miles northwest of; Grassy Run No. 1 mine, 4-foot bed (about 1,200 feet southwest of mine mouth, 4-foot 7-inch bed, 4-foot 6-inch cut).	306	13664	B	1	2.73	19.63	64.99	12.65	2.30	....	....	....	....	2.2	7,357	13,243
				2	....	20.18	66.81	13.01	2.36	....	....	....	....	....	7,564	13,615
				3	....	23.20	76.80	....	2.71	....	....	....	....	....	8,696	15,653
Holsopple, ½ mile north of; Lenore mine, B or Miller bed (rib of right entry 1, 200 feet from main entry, 3-foot 4½-inch bed, 3-foot 3½-inch cut).	307	15078	A	1	2.75	15.98	74.03	7.24	2.15	....	....	....	....	2.0	7,762	13,972
				2	....	16.43	76.13	7.44	2.21	....	....	....	....	....	7,982	14,368
				3	....	17.75	82.25	....	2.39	....	....	....	....	....	8,624	15,523
Same (face of south entry 3, 3-foot 7-inch bed and cut).	307	15079	A	1	2.32	16.73	72.98	7.97	2.64	....	....	....	....	1.9	7,796	14,033
				2	....	17.13	74.71	8.16	2.70	....	....	....	....	....	7,982	14,368
				3	....	18.65	81.35	....	2.94	....	....	....	....	....	8,691	15,644
Same (30 feet from face of main entry, 3-foot 3¾-inch bed and cut).	307	15080	A	1	1.94	17.07	72.41	8.58	2.61	....	....	....	....	1.5	7,761	13,970
				2	....	17.41	73.84	8.75	2.66	....	....	....	....	....	7,915	14,247
				3	....	19.08	80.92	....	2.92	....	....	....	....	....	8,674	15,613
Same (30 feet from face of south entry 7, 3-foot 1/16-inch bed and cut).	307	15081	A	1	1.81	17.36	73.16	7.67	2.23	....	....	....	....	1.4	7,900	14,220
				2	....	17.68	74.51	7.81	2.27	....	....	....	....	....	8,045	14,481
				3	....	19.18	80.82	....	2.46	....	....	....	....	....	8,726	15,707
Same (composite of samples 15079, 15080, and 15081).	307	15082	A	1	1.99	16.58	73.28	8.15	2.46	4.37	80.24	1.28	3.50	1.6	7,839	14,110
				2	....	16.92	74.76	8.32	2.51	4.23	81.87	1.31	1.76	....	7,998	14,396
				3	....	18.46	81.54	....	2.74	4.61	89.30	1.43	1.92	....	8,724	15,703
⅜ mile north of; Oneida mine, C′ bed (on pillar in room 6, off left entry 5, 3-foot 4-inch bed and cut).	308	15073	A	1	2.23	15.62	72.83	9.32	1.87	....	....	....	....	1.7	7,645	13,761
				2	....	15.98	74.49	9.53	1.91	....	....	....	....	....	7,819	14,074
				3	....	17.66	82.34	....	2.11	....	....	....	....	....	8,642	15,556
Same (face of room 3, off left entry 6, 3-foot 5⅞-inch bed and cut).	308	15074	A	1	1.99	17.73	69.54	10.74	2.90	....	....	....	....	1.5	7,539	13,570
				2	....	18.09	70.95	10.96	2.96	....	....	....	....	....	7,692	13,846
				3	....	20.32	79.68	....	3.32	....	....	....	....	....	8,639	15,550
Same (15 feet from face of left entry 5, 3-foot 7⅞-inch bed and cut).	308	15075	A	1	2.27	16.71	69.63	11.39	3.47	....	....	....	....	1.8	7,414	13,345
				2	....	17.10	71.25	11.65	3.55	....	....	....	....	....	7,586	13,655
				3	....	19.36	80.64	....	4.02	....	....	....	....	....	8,587	15,457
Same (face of room 23, off left entry 3, 4-foot bed and cut).	308	15076	A	1	1.85	17.34	68.94	11.87	2.77	....	....	....	....	1.4	7,430	13,374
				2	....	17.67	70.24	12.09	2.82	....	....	....	....	....	7,570	13,626
				3	....	20.10	79.90	....	3.21	....	....	....	....	....	8,611	15,500
Same (composite of samples 15074, 15075, and 15076).	308	15077	A	1	2.03	17.28	69.31	11.38	3.00	4.19	76.77	1.25	3.41	1.6	7,482	13,468
				2	....	17.64	70.74	11.62	3.06	4.04	78.36	1.28	1.64	....	7,637	13,747
				3	....	19.96	80.04	....	3.46	4.57	88.66	1.45	1.86	....	8,641	15,554
Jerome, near; Jerome No. 2 mine, C′ or Upper Kittanning bed (south entry 7, off east entry 1½, 6-foot 6-inch bed, 5-foot 3½-inch cut).	308	W19638	A	1	2.0	14.7	73.8	9.5	.90	....	....	....	....	....	7,650	13,770
				2	....	15.0	75.3	9.7	.90	....	....	....	....	....	7,806	14,050
				3	....	16.6	83.4	....	1.00	....	....	....	....	....	8,644	15,560
Same (face of south entry 4, east entry 2, 6-foot ½-inch bed, 5-foot 5-inch cut).	308	W19639	A	1	2.1	14.5	74.1	9.3	.70	....	....	....	....	....	7,722	13,900
				2	....	14.8	75.7	9.5	.70	....	....	....	....	....	7,889	14,200
				3	....	16.4	83.6	....	.77	....	....	....	....	....	8,722	15,700
Same (face of east entry 2, 6-foot ½-inch bed, 4-foot 9½-inch cut).	308	W19642	A	1	2.7	14.3	72.2	10.8	.90	....	....	....	....	....	7,506	13,510
				2	....	14.7	74.2	11.1	.95	....	....	....	....	....	7,717	13,890
				3	....	16.5	83.5	....	1.07	....	....	....	....	....	8,683	15,630
Same (composite of samples W19638, W19639, and W19642).	309	12224	A	1	1.44	15.21	73.38	9.97	.90	4.17	79.43	1.34	4.19	....	7,666	13,799
				2	....	15.43	74.45	10.12	.91	4.07	80.59	1.36	2.95	....	7,778	14,000
				3	....	17.17	82.83	....	1.01	4.53	89.66	1.51	3.29	....	8,654	15,577
Same (face of east entry 1).......................	309	12210	A	1	1.27	14.23	70.06	14.44	1.92	3.98	75.15	1.25	3.26	....	7,274	13,093
				2	....	14.41	70.96	14.63	1.94	3.89	76.12	1.27	2.15	....	7,368	13,262
				3	....	16.88	83.12	....	2.27	4.56	89.17	1.49	2.51	....	8,631	15,536

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
SOMERSET COUNTY—continued.																
Pinehill, 2 miles southwest of Berlin; Consolidation No. 112 mine, Little Pittsburgh bed (room 44, off right subentry 8, off west main entry, about 3,600 feet southwest of mine mouth, 3-foot 7-inch bed and cut).	309	13981	B	1	2.21	21.48	67.29	9.02	2.29	......	......	......	......	1.3	7,658	13,784
				2	......	21.97	68.81	9.22	2.34	......	......	......	......	......	7,831	14,096
				3	......	24.20	75.80	......	2.58	......	......	......	......	......	8,627	15,529
Same (room 8, right subentry 1, off left entry 12, about 5,000 feet southwest of mine mouth, 3-foot 1-inch cut).	309	13982	B	1	3.09	21.58	68.51	6.82	1.04	......	......	......	......	1.9	7,767	13,981
				2	......	22.27	70.69	7.04	1.07	......	......	......	......	......	8,015	14,427
				3	......	23.96	76.04	......	1.15	......	......	......	......	......	8,622	15,520
Same (composite of samples 13981 and 13982)	309	14037	B	1	2.58	21.53	67.97	7.92	1.66	4.69	78.88	1.72	5.13	1.6	7,724	13,903
				2	......	22.10	69.77	8.13	1.70	4.52	80.97	1.77	2.91	......	7,929	14,272
				3	......	24.06	75.94	......	1.85	4.92	88.14	1.93	3.16	......	8,631	15,536
2 miles southwest of Berlin; Consolidation No. 113 mine, "Stoner" bed (from mine car brought from room 2, off right entry 10, about 3,700 feet southwest of mine mouth.	309	13984	B	1	3.43	19.14	66.61	10.82	1.89	......	......	......	......	2.7	7,398	13,316
				2	......	19.82	68.98	11.20	1.96	......	......	......	......	......	7,661	13,790
				3	......	22.32	77.68	......	2.21	......	......	......	......	......	8,627	15,529
Ralphton, ½ mile east of; Ralphton No. 3 mine, C′ or Upper Kittanning bed (third crosscut off south entry 2, 3,050 feet from mine mouth, 3-foot 11½-inch bed, 3-foot 3-inch cut).	310	W19627	A	1	2.2	15.8	74.2	7.8	.60	......	......	......	......	......	7,850	14,130
				2	......	16.2	75.8	8.0	.60	......	......	......	......	......	8,028	14,450
				3	......	17.6	82.4	......	.65	......	......	......	......	......	8,728	15,710
Same (face of room 11, off straight main entry, 3,150 feet from mine mouth, 3-foot 5¾-inch cut).	310	W19628	A	1	2.1	15.2	73.9	8.8	.80	......	......	......	......	......	7,794	14,030
				2	......	15.5	75.5	9.0	.80	......	......	......	......	......	7,967	14,340
				3	......	17.0	83.0	......	.88	......	......	......	......	......	8,756	15,760
Same (face of room 4, off right entry 6, 2,800 feet from mine mouth, 3-foot 4½-inch cut).	310	W19629	A	1	1.9	16.4	73.7	8.0	.70	......	......	......	......	......	7,861	14,150
				2	......	16.7	75.1	8.2	.70	......	......	......	......	......	8,011	14,420
				3	......	18.2	81.8	......	.76	......	......	......	......	......	8,722	15,700
Same (face of room 29, off right heading 4, 2,900 feet from mine mouth, 3-foot 6½-inch cut).	310	W19630	A	1	2.1	15.8	74.2	7.9	.75	......	......	......	......	......	7,850	14,130
				2	......	16.1	75.8	8.1	.75	......	......	......	......	......	8,017	14,430
				3	......	17.5	82.5	......	.82	......	......	......	......	......	8,722	15,700
Same (third crosscut, off south entry 3, 3,700 feet from mine mouth, 3-foot 4½-inch cut).	210	W19631	A	1	2.0	15.5	73.2	9.5	.65	......	......	......	......	......	7,772	13,990
				2	......	15.6	74.7	9.7	.65	......	......	......	......	......	7,933	14,280
				3	......	17.3	82.7	......	.72	......	......	......	......	......	8,783	15,810

Same (composite of samples W19627, W19628, W19629, W19630, and W19631).	310	12228	A	1	1.23	15.49	74.77	8.51	.71	4.35	81.14	1.45	3.84	......	7,872	14,170
				2	......	15.68	75.70	8.62	.72	4.26	82.15	1.47	2.78	......	7,970	14,346
				3	......	17.16	82.84	......	.79	4.66	89.90	1.61	3.04	......	8,722	15,700
1¾ miles north of: Ralphton No. 4 mine, C′ or Upper Kittanning bed (face of south main entry, 3-foot 10½-inch bed and cut).	311	W19633	A	1	2.4	15.2	74.5	7.9	.65	......	......	......	......	......	7,822	14,080
				2	......	15.6	76.3	8.1	.65	......	......	......	......	......	8,011	14,420
				3	......	17.0	83.0	......	.71	......	......	......	......	......	8,717	15,690
Same (face of room 7, off south main entry, 3-foot 7½-inch bed and cut).	311	W19635	A	1	2.2	15.3	74.7	7.8	.55	......	......	......	......	......	7,894	14,210
				2	......	15.6	76.4	8.0	.55	......	......	......	......	......	8,072	14,530
				3	......	17.0	83.0	......	.60	......	......	......	......	......	8,772	15,790
Same (face of left entry 4, off south main entry, 3-foot 11-inch bed and cut).	311	W19637	A	1	2.1	14.3	75.9	7.7	.60	......	......	......	......	......	7,900	14,220
				2	......	14.6	77.5	7.9	.60	......	......	......	......	......	8,072	14,530
				3	......	15.9	84.1	......	.65	......	......	......	......	......	8,767	15,780
Same (composite of samples W19633, W19635, and W19637).	311	12202	A	1	1.33	14.97	75.75	7.95	.66	4.28	81.59	1.35	4.17	......	7,892	14,206
				2	......	15.17	76.77	8.06	.67	4.19	82.69	1.37	3.02	......	7,999	14,398
				3	......	16.50	83.50	......	.73	4.56	89.94	1.49	3.28	......	8,701	15,662
Same (pillar between south main heading and air course, opposite right entry 1, 3-foot 11½-inch bed and cut).	311	W19632	A	1	1.9	15.7	74.5	7.9	.65	......	......	......	......	......	7,894	14,210
				2	......	16.0	75.9	8.1	.65	......	......	......	......	......	8,044	14,480
				3	......	17.4	82.6	......	.71	......	......	......	......	......	8,756	15,760
Same (on pillar, at second "shoo-fly," off first main entry, 3-foot 7-inch bed and cut).	311	W19636	A	1	2.6	15.2	75.1	7.1	.70	......	......	......	......	......	7,911	14,240
				2	......	15.6	77.1	7.3	.70	......	......	......	......	......	8,128	14,630
				3	......	16.8	83.2	......	.76	......	......	......	......	......	8,767	15,780
Same (composite of samples W19632 and W19636).	311	12218	A	1	1.52	15.78	74.93	7.77	.66	4.36	82.09	1.43	3.69	......	7,936	14,285
				2	......	16.02	76.09	7.89	.67	4.25	83.35	1.45	2.39	......	8,058	14,504
				3	......	17.39	82.61	......	.73	4.61	90.49	1.57	2.60	......	8,749	15,748
WASHINGTON COUNTY.																
Avella, 2 miles west of; Penobscott mine, Pittsburgh bed (room 15, off eighth left entry, off main entry, 2,500 feet northwest of mine mouth; 5-foot 4½-inch bed, 4-foot 11-inch cut).	311	15673	B	1	4.31	37.00	52.85	5.84	1.90	5.31	74.14	1.53	11.28	2.1	7,391	13,304
				2	......	38.67	55.23	6.10	1.99	5.05	77.48	1.60	7.78	......	7,724	13,903
				3	......	41.18	58.82	......	2.12	5.38	82.52	1.70	8.28	......	8,226	14,807
Same (room off right entry 7, 3,100 feet northeast of mine mouth; 4-foot 2-inch bed, 3-foot 10-inch cut).	311	15674	B	1	4.27	37.84	51.55	6.34	2.15	......	......	......	......	1.7	7,398	13,316
				2	......	39.53	53.85	6.62	2.25	......	......	......	......	......	7,728	13,910
				3	......	42.33	57.67	......	2.41	......	......	......	......	......	8,276	14,897
Baird, near; Schoenberger mine, Pittsburgh bed (face of room 10, off entry 32, off face entry 12, 4,000 feet southeast of mine mouth, 5-foot 6¼-inch bed, 5-foot 5-inch cut).	312	11164	A	1	2.29	34.62	57.52	5.57	1.04	......	......	......	......	1.1	......	......
				2	......	35.43	58.87	5.70	1.06	......	......	......	......	......	......	......
				3	......	37.57	62.43	......	1.12	......	......	......	......	......	......	......
Same (face of room 4, off entry 32, off face entry 11, 4,000 feet southeast of mine mouth, 5-foot 9⅝-inch bed, 5-foot 8¾-inch cut).	312	11165	A	1	2.68	34.05	57.40	5.87	1.23	......	......	......	......	1.6	......	......
				2	......	34.99	58.98	6.03	1.26	......	......	......	......	......	......	......
				3	......	37.24	62.76	......	1.34	......	......	......	......	......	......	......
Same (face of right main entry, 7,000 feet south of mine mouth, 5-foot 2¾-inch bed, 5-foot 2⅛-inch cut).	312	11166	A	1	9.48	30.96	53.52	6.04	.97	......	......	......	......	8.4	......	......
				2	......	34.20	59.13	6.67	1.07	......	......	......	......	......	......	......
				3	......	36.65	63.35	......	1.15	......	......	......	......	......	......	......
Same (face of room 11, off entry 32, off right main entry, 6,000 feet south of mine mouth, 5-foot 7½-inch bed, 5-foot 6½-inch cut).	312	11167	A	1	3.54	33.01	57.85	5.60	.98	......	......	......	......	2.3	......	......
				2	......	34.22	59.97	5.81	1.02	......	......	......	......	......	......	......
				3	......	36.33	63.67	......	1.08	......	......	......	......	......	......	......
Same (face of face entry 11, 4,800 feet southeast of mine mouth, 5-foot 6¾-inch bed, 5-foot 5¾-inch cut).	312	11168	A	1	3.94	33.63	56.63	5.80	.90	......	......	......	......	2.7	......	......
				2	......	35.01	58.95	6.04	.94	......	......	......	......	......	......	......
				3	......	37.26	62.74	......	1.00	......	......	......	......	......	......	......

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PENNSYLVANIA—Continued.																
WASHINGTON COUNTY—continued.																
Baird, near; Schoenberger mine, Pittsburgh bed (pillar, in right entry 29, off main entry, 5,500 feet south of mine mouth, 5-foot 2-inch bed, 5-foot ½-inch cut).	312	11169	A	1	2.63	34.32	57.60	5.45	1.09	......	......	......	......	1.4	......	......
				2	......	35.25	59.15	5.60	1.12	......	......	......	......	......	......	......
				3	......	37.34	62.66	......	19.1	......	......	......	......	......	......	......
Same (composite of samples 11164-11691)........	312	11170	A	1	3.94	33.55	56.81	5.70	1.04	5.33	77.21	1.37	9.35	2.9	7,676	13,817
				2	......	34.93	59.14	5.93	1.08	5.09	80.38	1.43	6.09	......	7,991	14,384
				3	......	37.13	62.87	......	1.15	5.41	85.44	1.52	6.48	......	8,494	15,290
Finleyville, 2 miles from; Cincinnati mine, Pittsburgh bed (butt entry 6, off face entry 14, 60 feet outby last cut-through, 6,200 feet northwest of Mingo slope mouth, 5-foot 8½-inch bed and cut).	313	17082	A	1	2.79	35.17	55.30	6.74	1.05	......	......	......	......	1.6	7,564	13,615
				2	......	36.18	56.89	6.93	1.08	......	......	......	......	......	7,781	14,006
				3	......	38.88	61.12	......	1.16	......	......	......	......	......	8,361	15,050
Same (butt entry 10, off face entry 14, 60 feet inby room 2, 6,800 feet northwest of Mingo slope mouth, 6-foot 1½-inch bed, 5-foot 5½-inch cut).	313	17083	A	1	3.22	35.10	55.76	5.92	1.18	......	......	......	......	2.1	7,592	13,666
				2	......	36.27	57.61	6.12	1.17	......	......	......	......	......	7,845	14,121
				3	......	38.63	61.37	......	1.25	......	......	......	......	......	8,356	15,041
Same (butt entry 12, off face entry 14, inby first crosscut, 7,400 feet northwest of Mingo slope mouth, 6-foot 3½-inch bed and cut).	313	17084	A	1	2.87	35.75	54.88	6.50	1.32	......	......	......	......	1.5	7,609	13,696
				2	......	36.80	56.51	6.69	1.36	......	......	......	......	......	7,833	14,099
				3	......	39.44	60.56	......	1.46	......	......	......	......	......	8,395	15,111
Same (composite of samples 17082, 17083, and 17084).	313	17085	A	1	3.03	35.22	55.36	6.39	1.19	5.52	77.05	1.41	8.44	1.8	7,586	13,655
				2	......	36.32	57.09	6.59	1.23	5.34	79.45	1.45	5.94	......	7,823	14,081
				3	......	38.88	61.12	......	1.32	5.72	85.05	1.55	6.36	......	8,375	15,075
Monongahela City; Catsburg mine, Pittsburgh bed (face of butt entry 66, 2¼ miles northeast of mine mouth, 5-foot 6-inch bed, 5-foot 5-inch cut).	314	11157	A	1	2.78	33.58	57.15	6.49	1.06	......	......	......	......	1·7	......	......
				2	......	34.54	58.78	6.68	1.09	......	......	......	......	......	......	......
				3	......	37.01	62.99	......	1.17	......	......	......	......	......	......	......
Same (rib of room 17, off entry 75, 2¼ miles northeast of mine mouth, 4-foot 5⅞-inch bed, 4-foot 3½-inch cut).	314	11158	A	1	2.68	33.44	58.07	5.81	.82	......	......	......	......	1.6	......	......
				2	......	34.36	59.67	5.97	.84	......	......	......	......	......	......	......
				3	......	36.54	63.46	......	.89	......	......	......	......	......	......	......
Same (face of room 23, off butt entry 79, 2¾ miles north of mine mouth, 5-foot 2½-inch bed, 5-foot 1½-inch cut).	314	11159	A	1	3.10	33.27	57.79	5.84	1.02	......	......	......	......	1.9	......	......
				2	......	34.33	59.64	6.03	1.05	......	......	......	......	......	......	......
				3	......	36.53	63.47	......	1.12	......	......	......	......	......	......	......

Same (chain pillar at room 46, off butt entry 74, 2½ miles northwest of mine mouth), 5-foot 6¾-inch bed, 5-foot 5½-inch cut).	314	11160	A	1	2.70	32.78	58.01	6.51	.84	......	......	......	......	1.6	......	......
				2	......	33.69	59.61	6.70	.86	......	......	......	......	......	......	......
				3	......	36.11	63.89	......	.92	......	......	......	......	......	......	......
Same (face of north second main entry, 2¾ miles north of mine mouth, 5-foot 6-inch bed, 5-foot 4½-inch cut).	314	11161	A	1	2.94	33.69	55.73	7.64	2.03	......	......	......	......	1.9	......	......
				2	......	34.71	57.42	7.87	2.09	......	......	......	......	......	......	......
				3	......	37.67	62.33	......	2.27	......	......	......	......	......	......	......
Same (face of room 101, off butt entry 68, 2¾ miles northwest of mine mouth, 5-foot 7½-inch cut).	314	11162	A	1	2.93	33.39	57.60	6.08	1.07	......	......	......	......	1.9	......	......
				2	......	34.40	59.34	6.26	1.10	......	......	......	......	......	......	......
				3	......	36.70	63.30	......	1.17	......	......	......	......	......	......	......
Same (composite of samples 11157–11162)........	314	11163	A	1	2.83	33.51	57.29	6.37	1.11	5.38	77.17	1.33	8.64	1.8	7,704	13,867
				2	......	34.49	58.95	6.56	1.14	5.22	79.42	1.37	6.29	......	7,928	14,270
				3	......	36.91	63.09	......	1.22	5.59	85.00	1.47	6.72	......	8,485	15,273
Same (from car of slack, sampled at Pittsburgh experiment station).	314	11172	C	1	2.82	31.58	55.13	10.47	1.21	4.98	73.53	1.32	8.49	1.7	7,314	13,165
				2	......	32.50	56.73	10.77	1.25	4.81	75.66	1.36	6.15	......	7,526	13,547
				3	......	36.42	63.58	......	1.40	5.39	84.79	1.52	6.90	......	8,434	15,181
Same (from car of slack, sampled at Pittsburgh experiment station).	314	11541	C	1	3.82	32.34	52.23	11.61	1.81	5.03	72.16	1.28	8.11	2.6	7,115	12,807
				2	......	33.62	54.31	12.07	1.88	4.79	75.02	1.33	4.91	......	7,397	13,315
				3	......	38.24	61.76	......	2.14	5.45	85.32	1.51	5.58	......	8,413	15,143
Same (from car of slack, sampled at Pittsburgh experiment station).	314	12281	C	1	2.08	31.48	54.66	11.78	1.17	4.91	72.65	1.45	8.04	.6	7,248	13,046
				2	......	32.15	55.82	12.03	1.19	4.78	74.19	1.48	6.33	......	7,402	13,324
				3	......	36.55	63.45	......	1.35	5.43	84.34	1.68	7.20	......	8,415	15,147
WESTMORELAND COUNTY.																
Greensburg, 4 miles north of; No. 4 mine, Pittsburgh or No. 8 bed (from car of lump coal, sampled at Pittsburgh experiment station).	314	12265	C	1	2.14	30.02	58.81	9.03	1.17	5.03	76.33	1.56	6.88	.8	7,590	13,662
				2	......	30.68	60.09	9.23	1.20	4.89	78.00	1.59	5.09	......	7,756	13,961
				3	......	33.80	66.20	......	1.32	5.39	85.93	1.75	5.61	......	8,545	15,381
Same (from car of lump coal, sampled at Pittsburgh experiment station).	314	12853	C	1	2.51	30.28	56.82	10.39	1.37	4.98	74.65	1.51	7.10	1.8	7,425	13,365
				2	......	31.06	58.28	10.66	1.41	4.82	76.57	1.55	4.99	......	7,616	13,709
				3	......	34.77	65.23	......	1.58	5.40	85.70	1.73	5.59	......	8,525	15,345
Lucesco, ½ mile south of; Lucesco mine, Upper Freeport bed (face of left entry 9; 4,000 feet south of mine mouth, 3-foot 6-inch bed, 3-foot 4½-inch cut).	315	12393	A	1	2.91	33.68	50.09	13.32	4.10	......	......	......	......	1.4	......	......
				2	......	34.69	51.59	13.72	4.22	......	......	......	......	......	......	......
				3	......	40.21	59.79	......	4.89	......	......	......	......	......	......	......
Same (face of left entry 5, 165 feet beyond room 46; 3,600 feet from mine mouth, 3-foot 10-inch bed, 3-foot 8½-inch cut).	315	12394	A	1	2.92	35.46	52.29	9.33	3.17	......	......	......	......	1.4	......	......
				2	......	36.53	53.86	9.61	3.27	......	......	......	......	......	......	......
				3	......	40.41	59.59	......	3.62	......	......	......	......	......	......	......
Same (face of room 48, off right entry 1, 3,200 feet southeast of mine mouth, 3-foot 11-inch bed, 3-foot 8-inch cut).	315	12395	A	1	2.65	36.27	52.09	8.99	2.39	......	......	......	......	1.1	......	......
				2	......	37.26	53.51	9.23	2.46	......	......	......	......	......	......	......
				3	......	41.05	58.95	......	2.71	......	......	......	......	......	......	......
Same (face of room 20, off right entry; 3 2,300 feet southeast of mine mouth, 3-foot 8-inch bed, 3-foot 6-inch cut).	315	12396	A	1	2.57	34.83	52.28	10.32	3.03	......	......	......	......	1.0	......	......
				2	......	35.75	53.66	10.59	3.11	......	......	......	......	......	......	......
				3	......	39.98	60.02	......	3.48	......	......	......	......	......	......	......
Same (composite of samples 12393–12396)........	315	12397	A	1	2.71	35.72	50.87	10.70	3.11	5.00	72.08	1.24	7.87	1.2	7,280	13,104
				2	......	36.72	52.28	11.00	3.20	4.83	74.09	1.27	5.61	......	7,483	13,469
				3	......	41.26	58.74	......	3.60	5.43	83.25	1.43	6.29	......	8,408	15,134
Madison, Keystone mine, Pittsburgh bed (slack)........	315	16270	C	1	3.26	30.68	55.01	11.05	1.49	4.96	72.97	1.41	8.12	2.5	7,231	13,016
				2	......	31.71	56.87	11.42	1.54	4.76	75.43	1.46	5.39	......	7,475	13,455
				3	......	35.80	64.20	......	1.74	5.37	85.15	1.65	6.09	......	8,439	15,190
Same (run of mine)............................	315	16271	C	1	1.94	32.75	55.78	9.53	1.88	5.05	75.40	1.58	6.56	1.2	7,514	13,525
				2	......	33.40	56.88	9.72	1.92	4.93	76.89	1.61	4.93	......	7,663	13,793
				3	......	37.00	63.00	......	2.13	5.46	85.17	1.78	5.46	......	8,488	15,278

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SOUTH DAKOTA.																
HARDING COUNTY.																
Buffalo, 18 miles east of; sec. 1, T. 17 N., R. 7 E., open pit (face of pit, 6-foot 7-inch bed, 6-foot 1¾-inch cut).	316	*13220	B	1	41.49	24.00	24.35	10.16	0.55	....	....	....	....	34.7	3,140	5,652
				2	....	41.02	41.62	17.36	.94	....	....	....	....	....	5,367	9,661
				3	....	49.64	50.36	....	1.14	....	....	....	....	....	6,495	11,691
10 miles north of, sec. 6, T. 20 N., R. 5 E., Hilton mine (face of entry, 120 feet from outcrop at mouth of entry).	316	*13221	B	1	39.80	25.31	23.81	11.08	.96	....	....	....	....	33.0	3,046	5,483
				2	....	42.04	39.56	18.40	1.59	....	....	....	....	....	5,060	9,108
				3	....	51.52	48.48	....	1.95	....	....	....	....	....	6,201	11,162
18 miles east of; sec. 1, T. 17 N., R. 7 E., open pit (face of pit, 11-foot 5-inch bed, 6-foot 3-inch cut).	316	*13222	B	1	41.09	25.84	23.95	9.12	1.14	....	....	....	....	34.3	2,953	5,315
				2	....	43.86	40.66	15.48	1.94	....	....	....	....	....	5,013	9,023
				3	....	51.90	48.10	....	2.30	....	....	....	....	....	5,931	10,676
Ralph, 5 miles southeast of; sec. 10, T. 20 N., R. 9 E.; Newcomb mine, Widow Clark bed (fresh face of open pit, 10-foot 10-inch bed, 10-foot 1-inch cut).	317	*15062	B	1	34.75	27.19	28.96	9.10	.95	....	....	....	....	26.6	3,474	6,253
				2	....	41.67	44.38	13.95	1.46	....	....	....	....	....	5,324	9,583
				3	....	48.42	51.58	....	1.70	....	....	....	....	....	6,187	11,137
PERKINS COUNTY.																
Lodgepole, 3 miles southwest of; sec. 29, T. 21 N., R. 12 E.; Nelson mine, (in entry 140 feet northwest of entry mouth, 7-foot cut).	317	*14354	B	1	33.30	28.95	27.26	10.49	.76	....	....	....	....	21.2	3,864	6,955
				2	....	43.40	40.87	15.73	1.14	....	....	....	....	....	5,793	10,427
				3	....	51.50	48.50	....	1.35	....	....	....	....	....	6,875	12,375
Strool, 6 miles northwest of; sec. 35, T. 19 N., R. 10 E.; Jones mine (end of main entry, 5-foot 4½-inch bed, 4-foot 2-inch cut).	318	*12453	B	1	39.16	24.68	27.81	8.35	2.22	6.60	38.02	.53	44.28	26.0	3,504	6,307
				2	....	40.57	45.71	13.72	3.65	3.70	62.49	.87	15.57	....	5,760	10,368
				3	....	47.02	52.98	....	4.23	4.29	72.43	1.01	18.04	....	6,676	12,017
5 miles southwest of; sec. 2, T. 17 N., R. 10 E.; Knudsen mine (end of second entry, 3-foot 6-inch bed, 2-foot 7-inch cut).	318	*12454	B	1	34.69	26.42	27.64	11.25	1.08	....	....	....	....	19.6	....	....
				2	....	40.45	42.32	17.23	1.65	....	....	....	....	....	....	....
				3	....	48.87	51.13	....	1.99	....	....	....	....	....	....	....
5 miles south of; sec. 17, T. 17 N., R. 11 W.; Phillips mine (in mine, 150 feet from mine mouth, 2-foot 5-inch bed).	318	*12488	B	1	42.46	23.24	25.30	9.00	1.16	7.07	35.22	0.62	46.93	30.1	3,308	5,954
				2	....	40.39	43.97	15.64	2.02	4.08	61.21	1.08	15.97	....	5,749	10,348
				3	....	47.88	52.12	....	2.39	4.84	72.56	1.28	18.93	....	6,815	12,267

TENNESSEE.

ANDERSON COUNTY.

Briceville, ½ mile west of; Cross Mountain No. 1 mine, Coal Creek bed (on right rib of left entry 26, outby last break-through to the right, 3-foot 8-inch bed, 3-foot 7-inch cut).	319	13237	A	1	1.55	35.36	56.49	6.60	.75	5.08	78.39	1.83	7.35	0.5	7,804	14,047
				2	......	35.92	57.38	6.70	.76	4.99	79.62	1.86	6.07	......	7,927	14,269
				3	......	38.50	61.50	......	.81	5.35	85.34	1.99	6.51	......	8,496	15,293
Same, chain pillar on right entry 27 (18 feet outby twelfth and last break-through, 3-foot 10-inch bed and cut).	319	13238	A	1	1.86	33.00	53.61	11.53	.76	4.78	74.21	1.76	6.96	.7	7,306	13,151
				2	......	33.63	54.62	11.75	.77	4.66	75.62	1.79	5.41	......	7,445	13,401
				3	......	38.11	61.89	......	.87	5.28	85.09	2.03	6.13	......	8,436	15,185
Same (room 3 off left entry 26)	319	13264	A	1	1.70	35.02	53.14	10.14	1.06	4.97	75.32	1.80	6.71	.5	7,479	13,462
				2	......	35.63	54.05	10.32	1.08	4.86	76.62	1.83	5.29	......	7,608	13,694
				3	......	39.73	60.27	......	1.20	5.42	85.44	2.04	5.90	......	8,484	15,271
Same (room 2 off left entry 26)	319	13265	A	1	1.47	35.93	53.39	9.21	1.03	5.18	75.03	1.84	7.76	.5	7,564	13,615
				2	......	36.47	54.18	9.35	1.05	5.04	76.15	1.87	6.54	......	7,677	13,819
				3	......	40.23	59.77	......	1.16	5.56	84.00	2.06	7.22	......	8,468	15,242
Same (right rib of right entry 27, about 30 feet from main entry, 4-foot bed and cut).	319	13290	A	1	1.88	34.96	54.58	8.58	.78	5.15	76.79	1.81	6.89	.5	7,654	13,777
				2	......	35.63	55.63	8.74	.79	5.03	78.26	1.84	5.34	......	7,801	14,042
				3	......	39.04	60.96	......	.87	5.51	85.76	2.02	5.84	......	8,548	15,386
BLEDSOE COUNTY.																
Herbert, near; prospect, Sewanee (?) bed (in drift near mouth, 6-foot 4-inch cut).	320	10915	B	1	3.44	31.10	57.63	7.83	.56	......	......	......	......	1.9	7,485	13,473
				2	......	32.21	59.69	8.10	.58	......	......	......	......	......	7,751	13,952
				3	......	35.05	64.95	......	.63	......	......	......	......	......	8,434	15,181
near; prospect, Sewanee (?) bed (face of new opening, 10 feet in, 3-foot cut).	320	10916	B	1	5.32	28.81	59.62	6.25	.51	......	......	......	......	3.7	7,447	13,405
				2	......	30.43	62.97	6.60	.54	......	......	......	......	......	7,866	14,159
				3	......	32.58	67.42	......	.58	......	......	......	......	......	8,421	15,158
Litton, 2 miles northwest of, 15 miles northeast of Pikeville; A. L. Hale mine, Angel bed (8-foot bed and cut).	320	12584	B	1	3.33	27.89	63.17	5.61	1.88	......	......	......	......	2.2	7,850	14,130
				2	......	28.85	65.35	5.80	1.94	......	......	......	......	......	8,120	14,616
				3	......	30.63	69.37	......	2.06	......	......	......	......	......	8,620	15,516
4 miles north of; prospect (in main entry, 60 feet from entry mouth).	320	10803	B	1	5.04	25.48	61.81	7.67	.59	......	......	......	......	3.9	7,493	13,487
				2	......	26.83	65.09	8.08	.62	......	......	......	......	......	7,891	14,204
				3	......	29.19	70.81	......	.67	......	......	......	......	......	8,585	15,453
Pikeville; 6 miles southwest of, J. W. McFarland prospect, Morgan Springs bed (in drift entry, 50 feet from outcrop, 21½-inch bed).	320	10731	B	1	2.17	33.80	53.40	10.63	3.53	......	......	......	......	1.0	7,361	13,250
				2	......	34.55	54.58	10.87	3.61	......	......	......	......	......	7,524	13,543
				3	......	38.77	61.23	......	4.05	......	......	......	......	......	8,442	15,196
About 10 miles west of; Vaughn Bros. prospect; Sewanee (?) bed (outcrop, 3-foot 9-inch bed).	321	11049	B	1	4.41	27.16	59.85	8.58	.93	......	......	......	......	2.8	7,302	13,144
				2	......	28.41	62.61	8.98	.97	......	......	......	......	......	7,639	13,750
				3	......	31.21	68.79	......	1.07	......	......	......	......	......	8,393	15,107
About 10 miles west of; Vaughn Bres. prospect; Sewanee (?) bed (outcrop, 3-foot 2-inch bed).	321	11050	B	1	4.38	26.66	62.37	6.59	.68	......	......	......	......	2.6	7,431	13,376
				2	......	27.88	65.23	6.89	.71	......	......	......	......	......	7,771	13,988
				3	......	29.94	70.06	......	.76	......	......	......	......	......	8,346	15,023
CUMBERLAND COUNTY.																
Litton, 4 miles north of; J. H. Hale & Son prospect, Sewanee (?) bed (in entry, 30 feet from entry mouth).	321	10800	B	1	4.30	25.71	62.51	7.48	.56	......	......	......	......	3.3	7,573	13,631
				2	......	26.86	65.33	7.81	.59	......	......	......	......	......	7,913	14,243
				3	......	29.14	70.86	......	.64	......	......	......	......	......	8,583	15,449
4 miles north of; J. H. Hale & Son prospect, Morgan Springs bed (in opening, 3-foot 6-inch bed).	321	10802	B	1	6.05	27.75	55.65	10.55	3.11	......	......	......	......	5.0	7,071	12,728
				2	......	29.54	59.23	11.23	3.31	......	......	......	......	......	7,526	13,547
				3	......	33.28	66.72	......	3.73	......	......	......	......	......	8,478	15,260

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
TENNESSEE—Continued.																
RHEA COUNTY.																
Dayton, near; North Pole mine, Richland bed (main heading of Craig workings, 3,000 feet from mine mouth, 25½-inch bed).	322	10689	B	1	1.91	29.67	54.39	14.03	1.43	4.71	71.50	1.41	6.92	0.7	7,109	12,796
				2	....	30.25	55.45	14.30	1.46	4.59	72.89	1.44	5.32	....	7,248	13,046
				3	....	35.30	64.70	....	1.70	5.36	85.06	1.68	6.20	....	8,458	15,224
Same (face of room off left heading 5, Craig workings, about 2,600 feet from mine mouth, 23-inch cut).	322	10690	B	1	1.90	29.68	53.44	14.98	1.65	4.08	71.09	1.40	6.20	.7	7,042	12,676
				2	....	30.26	54.47	15.27	1.68	4.56	72.46	1.13	4.60	....	7,179	12,922
				3	....	35.71	64.29	....	1.98	5.38	85.52	1.09	5.43	....	8,473	15,251
Same (floor of room off left heading 5, Craig workings, 2,600 feet from mine mouth, 30-inch cut).	322	10691	B	1	2.19	14.38	16.23	67.20	.33	2.25	21.55	.45	8.22	.8	2,026	3,647
				2	....	14.70	16.59	68.71	.34	2.06	22.03	.40	6.40	....	2,071	3,728
				3	....	46.98	53.02	....	1.09	6.58	70.41	1.47	20.45	....	6,619	11,914
Same (face of left heading 8, 3,000 feet from mine mouth, 22-inch bed).	322	10692	B	1	1.96	28.79	57.46	11.79	1.78	4.85	74.43	1.26	5.89	.9	7,343	13,217
				2	....	29.37	58.60	12.03	1.82	4.72	75.92	1.29	4.22	....	7,490	13,482
				3	....	33.39	66.61	....	2.06	5.37	86.31	1.47	4.79	....	8,515	15,327
Same (face of right heading 7, between 2,700 and 2,800 feet from mine mouth, 2-foot bed).	322	10693	B	1	2.08	27.91	55.10	14.91	.65	4.76	71.49	1.18	7.01	1.0	7,017	12,631
				2	....	28.50	56.27	15.23	.66	4.63	73.01	1.21	5.26	....	7,166	12,899
				3	....	33.62	66.38	....	.78	5.46	86.13	1.43	6.20	....	8,454	15,217
New Prospect mine, Nelson bed (face of room off left heading 3, 1,200 feet from mine mouth, 3-foot cut).	322	10696	B	1	1.76	27.86	49.57	20.81	.49	4.51	66.24	1.19	6.76	.8	6,481	11,666
				2	....	28.36	50.46	21.18	.50	4.39	67.43	1.21	5.29	....	6,597	11,875
				3	....	35.98	64.02	....	.63	5.57	85.55	1.54	6.71	....	8,370	15,066
Same (face of room off left heading 2, 2-foot 3-inch cut).	322	10697	B	1	3.08	29.77	52.75	14.40	.50	....	....	....	....	2.0	....	....
				2	....	30.72	54.42	14.86	.52	....	....	....	....	....	....	....
				3	....	36.08	63.92	....	.61	....	....	....	....	....	....	....
Same (end of right heading 3, 3-foot 2-inch cut)...	322	10698	B	1	1.93	27.86	49.17	21.04	.46	....	....	....	....	.8	....	....
				2	....	28.40	50.15	21.45	.47	....	....	....	....	....	....	....
				3	....	36.16	63.84	....	.60	....	....	....	....	....	....	....
Same (main heading, 1,500 to 1,600 feet from mine mouth).	322	10699	B	1	4.34	28.21	51.82	15.63	.46	....	....	....	....	3.2	....	....
				2	....	29.49	54.17	16.34	.48	....	....	....	....	....	....	....
				3	....	35.25	64.75	....	.57	....	....	....	....	....	....	....

UTAH.

CARBON COUNTY.

Hiawatha; Hiawatha No. 1 mine, Hiawatha bed (face of room 7, off left entry 1, 11-foot 2-inch bed and cut).	323	10904	A	1	7.57	39.10	47.80	5.53	.71					4.3		
				2		42.30	51.72	5.98	.77							
				3		44.99	55.01		.82							
Same (face of left air course 2, 11-foot 5-inch bed and cut).	323	10905	A	1	7.36	39.67	47.09	5.88	.66					3.9		
				2		42.82	50.83	6.35	.71							
				3		45.72	54.28		.75							
Same (composite of samples 10904 and 10905).....	323	10906	A	1	7.49	39.72	47.17	5.62	.64	6.09	69.12	1.35	17.18	4.1	6,956	12,521
				2		42.94	50.98	6.08	.69	5.69	74.72	1.46	11.36		7,519	13,534
				3		45.72	54.28		.73	6.06	79.55	1.55	12.11		8,005	14,409
Hiawatha No. 2 mine, Hiawatha bed (face of room 2, off dip entry 2, 13-foot 3-inch bed, 10-foot 3-inch cut).	323	10907	A	1	5.84	40.10	46.31	7.75	.53					2.6		
				2		42.59	49.18	8.23	.56							
				3		46.41	53.59		.61							
Same (face of room 1, off rise entry 2, 11-foot 7-inch bed, 10-foot 5½-inch cut).	323	10908	A	1	5.41	41.25	46.94	6.40	.58					2.2		
				2		43.61	49.62	6.77	.61							
				3		46.78	53.22		.65							
Same (composite of samples 10907 and 10908).....	323	10909	A	1	5.65	40.79	46.61	6.95	.56	5.96	69.46	1.39	15.68	2.4	7,026	12,647
				2		43.23	49.40	7.37	.59	5.66	73.62	1.47	11.29		7,447	13,405
				3		46.67	53.33		.64	6.11	79.48	1.59	12.18		8,040	14,472
Price, 9 miles northeast of; sec. 7, T. 13 S., R. 11 E.; Jesse Knight prospect (face of entry, 90 feet northwest of entry mouth, 6-foot 8-inch bed, 6-foot 5-inch cut).	324	14678	B	1	5.68	41.87	47.68	4.77	.58					.3	7,021	12,638
				2		44.39	50.55	5.06	.61						7,444	13,399
				3		46.76	53.24		.64						7,841	14,114
Sunnyside, sec. 32, T. 14 S., R. 14 E.; No. 1 mine, lower bed (face of Fowler slope; 10-foot bed, 5-foot 5-inch cut).	324	12632	B	1	5.96	38.68	48.77	6.59	1.73	5.43	71.28	1.52	13.45	3.4	7,134	12,841
				2		41.13	51.86	7.01	1.84	5.07	75.80	1.62	8.66		7,586	13,655
				3		44.23	55.77		1.98	5.45	81.52	1.74	9.31		8,158	14,684
1 mile southeast of; sec. 4, T. 15 S., R. 14 E.; No. 3 mine, upper bed (rib of air course, 50 feet northwest of outlet, 6-foot 2-inch bed).	325	12546	B	1	5.95	38.10	48.82	7.13	.56					1.0	6,663	11,993
				2		40.51	51.91	7.58	.60						7,085	12,753
				3		43.83	56.17		.65						7,666	13,799
Same (face of second crosscut, off right entry 1, off No. 1 rise, 1½ miles southeast of mine mouth, 4-foot 8-inch bed).	325	12630	B	1	5.06	38.45	48.68	7.81	.51	5.54	70.72	1.58	13.84	1.5	7,011	12,620
				2		40.50	51.27	8.23	.54	5.25	74.49	1.66	9.83		7,385	13,293
				3		44.13	55.87		.59	5.72	81.17	1.81	10.71		8,047	14,485
1 mile southeast of, No. 3 mine, lower bed (on dip entry, about 2¾ miles southeast of opening at Sunnyside, 6-foot 10-inch bed).	325	12631	B	1	5.08	39.94	47.69	7.29	1.37					2.1	7,094	12,769
				2		42.08	50.24	7.68	1.44						7,474	13,453
				3		45.58	54.42		1.56						8,096	14,573
¾ mile south of; sec. 5, T. 15 S., R. 14 E.; prospect, lower bed (85 feet northeast of mouth of prospect tunnel, 13-foot 10-inch bed, 6-foot cut).	325	*12545	B	1	15.17	33.87	46.19	4.77	.60					2.5	5,293	9,527
				2		39.93	54.45	5.62	.71						6,239	11,230
				3		42.31	57.69		.75						6,610	11,898
About 8½ miles northwest of; sec. 32, T. 13 S., R. 13 E.; prospect (face of tunnel, 200 feet northwest of opening, 5-foot 7-inch bed).	325	12792	B	1	6.67	38.58	49.54	5.21	1.04					2.9	6,728	12,110
				2		41.34	53.08	5.58	1.11						7,209	12,976
				3		43.78	56.22		1.18						7,635	13,743
12 miles northwest of; sec. 23, T. 13 S., R. 12 E.; prospect (in entry, 200 feet southeast of entry mouth, 8-foot 6-inch bed, 8-foot 2½-inch cut).	326	14801	B	1	8.54	39.76	47.86	3.84	.48					5.3	7,115	12,807
				2		43.47	52.33	4.20	.52						7,780	14,004
				3		45.37	54.63		.54						8,121	14,618

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
UTAH—Continued.																
EMERY COUNTY.																
Emery, 4 miles south of; NE. ¼ NE. ¼ sec. 33, T. 22 S., R. 6 E.; Browning mine, I bed (back of entry, 165 feet northeast of mouth, 22-foot bed, 12-foot cut.)	326	12627	B	1	3.93	40.92	49.22	5.93	.39	5.52	73.02	1.25	13.89	0.3	7,203	12,965
				2	......	42.59	51.24	6.17	.41	5.29	76.01	1.30	10.82	......	7,498	13,496
				3	......	45.39	54.61	......	.44	5.64	81.01	1.39	11.52	......	7,991	14,384
4 miles southeast of; SE. ¼ NW. ¼ sec. 26, T. 22 S., R. 6 E., Casper mine, C bed, back end of main entry, 200 feet northwest of entry mouth, 9-foot 10-inch bed, 7-foot 3½-inch cut).	327	12652	B	1	5.21	39.06	41.61	14.12	.81	......	......	......	......	1.8	6,263	11,273
				2	......	41.21	43.89	14.90	.85	......	......	......	......	......	6,607	11,893
				3	......	48.43	51.57	......	1.00	......	......	......	......	......	7,764	13,975
12 miles south of; SW. ¼ SW. ¼ sec. 32, T. 23 S., R. 6 E.; surface prospect, I bed (cave in rock ledge, 12-foot 3-inch bed, 10-foot 5-inch cut).	327	*14903	B	1	16.67	34.29	41.94	7.10	1.12	......	......	......	......	8.5	5,277	9,499
				2	......	41.15	50.33	8.52	1.34	......	......	......	......	......	6,332	11,398
				3	......	44.98	55.02	......	1.46	......	......	......	......	......	6,922	12,460
2¼ miles east of; SE. ¼, SW. ¼ sec. 12, T. 22 S., R. 6 E.; Williams mine, I bed (back of main entry, 200 feet southeast of mine mouth).	328	12613	B	1	3.95	41.83	42.60	11.62	4.66	......	......	......	......	.9	6,661	11,990
				2	......	43.55	44.35	12.10	4.85	......	......	......	......	......	6,935	12,483
				3	......	49.55	50.45	......	5.52	......	......	......	......	......	7,890	14,202
SEVIER COUNTY.																
Emery, 15 miles south of; SW. ¼ NW. ¼ sec. 25, T. 24 S., R. 5 E.; surface prospect, A bed (near outcrop at prospect, 11-foot 3-inch bed, 11-foot cut).	328	*15061	B	1	18.41	33.86	42.16	5.57	.41	......	......	......	......	11.6	5,270	9,486
				2	......	41.50	51.67	6.83	.50	......	......	......	......	......	6,459	11,626
				3	......	44.54	55.46	......	.54	......	......	......	......	......	6,932	12,478
Fremont, 15 miles northeast of; SW. ¼ NW. ¼ sec. 3, T. 26 S., R. 4 E.; Hogan prospect, A bed (back end of drift, about 20 feet northwest of mouth, 5-foot 1-inch bed, 3-foot cut).	328	*15090	B	1	23.57	32.61	33.25	10.57	2.88	......	......	......	......	17.0	4,346	7,823
				2	......	42.67	43.50	13.83	3.77	......	......	......	......	......	5,686	10,235
				3	......	49.52	50.48	......	4.38	......	......	......	......	......	6,599	11,878
Salina, about 15 miles east of; sec. 7, T. 22 S., R. 3 E.; SW. ¼ SW. ¼; Kearns & Duggins mine, Duggins bed (in room off main entry, about 175 feet north of entry mouth, 3-foot 9-inch bed, 3-foot 7-inch cut).	329	15045	B	1	6.38	45.10	36.28	12.24	.44	......	......	......	......	3.1	6,529	11,752
				2	......	48.17	38.76	13.07	.47	......	......	......	......	......	6,974	12,553
				3	......	55.41	44.59	......	.54	......	......	......	......	......	8,022	14,440

SUMMIT COUNTY.																
Coalville, 6 miles northeast of; SW. ¼ sec. 24, T. 3 N., R. 5 E.; Rees-Grass Creek mine, Wasatch bed (in mine, 400 feet below surface, and 500 feet east of main slope, 8-foot 6½-inch bed and cut).	329	13216	B	1	12.18	42.18	42.25	3.39	1.90	5.80	63.77	1.27	23.87	4.5	6,254	11,257
				2		48.03	48.11	3.86	2.16	5.07	72.61	1.45	14.85		7,121	12,818
				3		49.96	50.04		2.25	5.27	75.52	1.51	15.45		7,407	13,333
1 mile southeast of; sec. 16, T. 2 N., R. 5 E.; Superior mine, Wasatch bed (in mine, 1,000 feet northwest of foot of slope, 7-foot 6-inch bed and cut).	329	13217	B	1	17.08	36.94	41.24	4.74	1.53					7.8	5,655	10,179
				2		44.55	49.73	5.72	1.85						6,820	12,276
				3		47.25	52.75		1.96						7,234	13,021
3 miles northeast of; SW. ¼ sec. 3, T. 2 N., R. 5 E; Wasatch mine, Wasatch bed (800-foot level, 3,000 feet northeast of main slope, 10-foot 6-inch bed and cut).	329	13218	B	1	13.61	41.28	41.03	4.08	1.37	5.84	62.11	1.06	25.54	5.3	6,100	10,980
				2		47.78	47.50	4.72	1.59	5.01	71.89	1.23	15.56		7,061	12,710
				3		50.15	49.85		1.67	5.26	75.45	1.29	16.33		7,411	13,340
UINTA COUNTY.																
Vernal, 7 miles north of; sec. 8, T. 3 S., R. 22 E.; Blue Bell mine (face of main entry, about 225 feet from mine mouth, 7-foot 8¼-inch bed, 6-foot 5¼-inch cut).	330	10712	B	1	9.73	37.19	43.50	9.53	1.49					1.8		
				2		41.22	48.22	10.56	1.65							
				3		46.09	53.91		1.84							
8 miles east of; Green mine (face of main entry, 75 feet from mine mouth, 4-foot 8¾-inch bed, 2-foot 6-inch cut).	330	10713	B	1	8.76	38.84	44.16	8.24	2.36					1.1		
				2		42.57	48.40	9.03	2.59							
				3		46.80	53.20		2.85							
About 20 miles west of; Reynolds mine, Mancos bed (at face of main entry about 210 feet from surface).	331	10812	B	1	11.25	35.61	46.43	6.71	.95					4.5	6,324	11,383
				2		40.13	52.31	7.56	1.07						7,126	12,827
				3		43.41	56.59		1.16						7,709	13,876
WASATCH COUNTY.																
Hanna, about 15 miles southwest of; sec. 26, T. 1 S., R. 9 W.; prospect (face of entry, 100 feet from mouth of entry, 24-foot 8-inch cut).	331	10998	B	1	14.58	38.48	41.00	5.94	.82					9.0	5,768	10,382
				2		45.05	48.00	6.95	.96						6,753	12,155
				3		48.42	51.58		1.03						7,257	13,063
About 3 miles east of; sec. 7, T. 1 S., R. 7 W.; Winchester prospect, Mancos bed (in entry, about 10 feet from entry mouth).	332	10997	B	1	27.40	32.14	37.87	2.59	.60					19.0	4,125	7,425
				2		44.27	52.16	3.57	.83						5,682	10,226
				3		45.91	54.09		.86						5,892	10,606
Heber, about 28 miles southeast of; sec. 31, T. 1 S., R. 10 E.; Cummings mine (surface exposure, 13-foot bed, 10-foot 6-inch cut).	332	11058	B	1	19.15	37.04	37.60	6.21	.69					5.6	4,846	8,723
				2		45.81	46.51	7.68	.85						5,994	10,789
				3		49.62	50.38		.92						6,493	11,687
VIRGINIA.																
DICKENSON COUNTY.																
Clintwood, 3 miles southeast of; Elbert Powers mine, Clintwood (?) bed (in main entry, 20 feet from mine mouth, 7-foot 10½-inch bed, 4-foot 8-inch cut).	332	14767	B	1	4.28	29.40	62.11	4.21	1.02					3.3		
				2		30.71	64.89	4.40	1.07							
				3		32.12	67.88		1.12							
Near, 20 miles north of Coeburn; Yeates mine, Clintwood bed (at end of right entry 1, off main entry, 100 feet from main entry, 4-foot 2¾-inch bed and cut).	333	14766	B	1	2.18	34.19	60.44	3.19	.85					1.2	8,108	14,594
				2		34.95	61.79	3.26	.87						8,289	14,920
				3		36.13	63.87		.90						8,568	15,422

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
VIRGINIA—Continued.																
HENRICO COUNTY.																
Gayton, 1 mile from, 5 miles north of Lorraine; Carbon Hill mine, C bed (in main gangway, opposite room 45, 3-foot 6-inch bed, 3-foot 4-inch cut).	333	15060	A	1	2.81	25.70	62.47	9.02	1.43	4.90	76.55	1.81	6.29	1.9	7,496	13,493
				2	......	26.44	64.28	9.28	1.47	4.72	78.76	1.86	3.91	......	7,713	13,883
				3	......	29.14	70.86	......	1.62	5.20	86.82	2.05	4.31	......	8,502	15,304
Same (in main gangway opposite room 32, 3-foot 3-inch bed, 2-foot 3-inch cut).	333	15062	A	1	2.54	16.28	70.24	10.94	1.31	......	......	......	......	1.9	......	......
				2	......	16.70	72.07	11.23	1.34	......	......	......	......	......	......	......
				3	......	18.81	81.19	......	1.51	......	......	......	......	......	......	......
1 mile from, 5 miles north of Lorraine; Carbon Hill mine, B bed (face of right gangway off slope 3, 20 feet beyond room 21, 4-foot 11-inch bed, 4-foot 9-inch cut).	333	15061	A	1	2.11	23.58	56.95	17.36	2.16	4.44	69.22	1.59	5.23	1.4	6,778	12,200
				2	......	24.09	58.18	17.73	2.21	4.30	70.72	1.62	3.42	......	6,924	12,463
				3	......	29.28	70.72	......	2.69	5.23	85.96	1.97	4.15	......	8,416	15,149
RUSSELL COUNTY.																
Dante, 2 miles north of; No. 2 mine, Upper Banner bed (face of butt heading off fourth left drift off McClure entry, 5-foot 2¼-inch bed, 5-foot 1-inch cut).	334	10734	A	1	2.34	35.23	56.16	6.27	.59	......	......	......	......	1.5	7,832	14,098
				2	......	36.08	57.50	6.42	.60	......	......	......	......	......	8,020	14,436
				3	......	38.56	61.44	......	.64	......	......	......	......	......	8,570	15,426
Same (room 16, off right heading 3, off first drift off McClure entry, 5-foot 1¾-inch bed, 4-foot 9½-inch cut).	334	10735	A	1	2.99	35.16	56.66	5.19	.59	......	......	......	......	2.1	7,860	14,148
				2	......	36.24	58.41	5.35	.61	......	......	......	......	......	8,102	14,584
				3	......	38.29	61.71	......	.64	......	......	......	......	......	8,560	15,408
Same (composite of samples 10734 and 10735).....	334	10736	A	1	2.76	34.96	56.51	5.77	.59	5.32	80.13	1.43	6.76	1.8	7,860	14,148
				2	......	35.95	58.12	5.93	.61	5.15	82.41	1.47	4.43	......	8,083	14,549
				3	......	38.21	61.79	......	.65	5.47	87.60	1.56	4.72	......	8,591	15,464
2 miles north of; No. 5 mine, Upper Banner bed (room 14, on right heading 5, off ninth drift, 5-foot 2½-inch bed, 5-foot ½-inch cut).	334	10737	A	1	2.29	35.18	57.79	4.74	.55	......	......	......	......	1.4	8,017	14,431
				2	......	36.00	59.15	4.85	.56	......	......	......	......	......	8,205	14,769
				3	......	37.84	62.16	......	.59	......	......	......	......	......	8,623	15,521
Same (butt on left heading 9, off ninth drift, 5-foot 5½-inch bed, 5-foot 3-inch cut).	334	10738	A	1	2.11	35.11	57.13	5.65	.56	......	......	......	......	1.2	7,931	14,276
				2	......	35.87	58.36	5.77	.58	......	......	......	......	......	8,102	14,584
				3	......	38.06	61.94	......	.62	......	......	......	......	......	8,598	15,476
Same (composite of samples 10737 and 10738).....	334	10739	A	1	2.07	35.90	56.70	5.33	.57	5.45	80.24	1.43	6.98	1.3	7,964	14,335
				2	......	36.66	57.90	5.44	.58	5.33	81.93	1.46	5.26	......	8,132	14,638
				3	......	38.77	61.23	......	.61	5.64	86.64	1.54	5.57	......	8,600	15,480

WISE COUNTY.																
Flat Gap, 2 miles east of; Reuben Bolling mine, Lower Bolling bed (in entry, 15 feet from mine mouth, 4-foot 1-inch bed, 2-foot 11-inch cut).	335	15174	B	1	6.92	30.37	54.57	8.14	.95	....	....	....	....	5.8	7,209	12,976
				2	....	32.63	58.63	8.74	1.02	....	....	....	....	....	7,745	13,941
				3	....	35.76	64.24	....	1.12	....	....	....	....	....	8,487	15,277
Glamorgan; Glamorgan No. 3 mine, Glamorgan bed (face of dip entry 2; 6,000 feet from mine mouth, 4-foot 5½-inch bed, 4-foot 3-inch cut).	335	15100	B	1	2.66	33.08	59.27	4.99	1.37	....	....	....	....	1.6	7,897	14,215
				2	....	33.98	60.89	5.13	1.41	....	....	....	....	....	8,113	14,603
				3	....	35.82	64.18	....	1.49	....	....	....	....	....	8,552	15,394
Same (face of Glady entry), 7,000 feet from mine mouth, 4-foot 4-inch bed, 4-foot 3-inch cut).	335	15101	B	1	3.26	31.30	59.07	6.37	.87	5.27	78.02	1.65	7.82	2.0	7,728	13,910
				2	....	32.35	61.07	6.58	.90	5.08	80.65	1.71	5.08	....	7,988	14,378
				3	....	34.63	65.37	....	.96	5.44	86.33	1.83	5.44	....	8,550	15,390
Pardee; Pardee mine, Pardee bed (face of main entry, 2,000 feet from mine mouth, 9-foot 7-inch bed and cut).	336	15099	B	1	2.29	33.84	54.66	9.21	1.56	4.99	74.46	1.57	8.21	1.0	7,421	13,358
				2	....	34.63	55.94	9.43	1.60	4.85	76.20	1.61	6.31	....	7,595	13,671
				3	....	38.23	61.77	....	1.77	5.35	84.13	1.78	6.97	....	8,386	15,095
WASHINGTON.																
KING COUNTY.																
Grand Ridge, 3 miles east of; NE. ¼ sec. 26 N., T. 24, R. 6 E.; Grand Ridge mine, No. 3 or Reynolds bed (left side of chute 4, 6-foot 2-inch bed, 3-foot 6-inch cut).	336	11736	B	1	15.92	36.04	38.47	9.57	.49	....	....	....	....	9.0	5,537	9,967
				2	....	42.86	45.76	11.38	.58	....	....	....	....	....	6,585	11,853
				3	....	48.36	51.64	....	.65	....	....	....	....	....	7,431	13,376
Same (No. 4 bed, north side of rock tunnel, where it cuts bed, 3-foot 5-inch bed, 3-foot 1-inch cut).	336	11737	B	1	15.60	33.41	30.36	20.63	2.27	....	....	....	....	9.6	4,662	8,392
				2	....	39.58	35.98	24.44	2.69	....	....	....	....	....	5,524	9,943
				3	....	52.38	47.62	....	3.56	....	....	....	....	....	7,311	13,160
Same (No. 7 bed, 7-foot 7½-inch bed, 5-foot 2-inch cut).	336	11738	B	1	16.45	34.63	36.38	12.54	.38	....	....	....	....	10.6	5,323	9,581
				2	....	41.45	43.54	15.01	.45	....	....	....	....	....	6,371	11,468
				3	....	48.77	51.23	....	.53	....	....	....	....	....	7,496	13,493
KITTITAS COUNTY.																
Ellensburg, 25 miles west of, sec. 22, T. 18 N., R. 15 E.; prospect, No. 7 bed (face of entry, 30 feet from entry mouth, 2-foot 10½-inch bed, 2-foot 9½-inch cut).	337	13266	B	1	10.42	30.33	36.43	22.82	1.13	....	....	....	....	6.7	4,988	8,978
				2	....	33.86	40.67	25.47	1.26	....	....	....	....	....	5,568	10,022
				3	....	45.43	54.57	....	1.69	....	....	....	....	....	7,471	13,448
25 miles west of, sec. 16, T. 18 N., R. 15 E.; prospect, No. 10d bed (face of entry, 35 feet from entry mouth, 3-foot 9½-inch bed, 3-foot 1½-inch cut).	337	13267	B	1	5.08	31.87	40.43	22.62	1.14	....	....	....	....	2.9	5,751	10,352
				2	....	33.58	42.59	23.83	1.20	....	....	....	....	....	6,059	10,906
				3	....	44.09	55.91	....	1.58	....	....	....	....	....	7,955	14,319
25 miles west of, sec. 22, T. 18 N., R. 15 E.; prospect, 9c bed (face of entry, 40 feet from entry mouth, 3-foot 6-inch bed, 3-foot 2-inch cut).	338	13268	B	1	7.45	37.52	47.88	7.15	.64	....	....	....	....	4.1	6,701	12,062
				2	....	40.54	51.73	7.73	.69	....	....	....	....	....	7,240	13,032
				3	....	43.94	56.06	....	.75	....	....	....	....	....	7,847	14,125
Roslyn, secs. 8 and 9, T. 20 N., R. 15 E.; Roslyn No. 1 mine, Roslyn bed (face of southwest slant entry, 4-foot 2½-inch bed and cut).	338	11522	A	1	4.22	36.59	46.28	12.91	.38	....	....	....	....	2.4	....	....
				2	....	38.20	48.32	13.48	.40	....	....	....	....	....	....	....
				3	....	44.15	55.85	....	.46	....	....	....	....	....	....	....
Same (face of east entry 1, 3-foot 11½-inch bed, 3-foot 9½-inch cut).	338	11523	A	1	3.91	36.86	46.48	12.75	.37	....	....	....	....	2.1	....	....
				2	....	38.36	48.37	13.27	.39	....	....	....	....	....	....	....
				3	....	44.23	55.77	....	.45	....	....	....	....	....	....	....
Same (face of west entry 2, 3-foot 11¾-inch bed and cut).	338	11524	A	1	4.08	37.23	46.96	11.73	.39	....	....	....	....	2.5	....	....
				2	....	38.81	48.96	12.23	.41	....	....	....	....	....	....	....
				3	....	44.22	55.78	....	.47	....	....	....	....	....	....	....
Same (composite of samples 11522–11524)	338	11525	A	1	3.89	37.00	46.49	12.62	.37	5.58	68.55	1.31	11.57	2.3	6,908	12,434
				2	....	38.50	48.37	13.13	.38	5.36	71.33	1.36	8.44	....	7,188	12,938
				3	....	44.32	55.68	....	.44	6.17	82.11	1.57	9.71	....	8,274	14,893

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WASHINGTON—Continued.																
KITTITAS COUNTY—continued.																
Roslyn; Roslyn No. 2 mine, Roslyn bed (face of main slope, 4-foot 8-inch bed and cut).	338	11526	A	1	3.77	37.69	47.05	11.49	.47	5.58	70.17	1.52	10.77	2.2	7,090	12,762
				2	....	39.17	48.89	11.94	.49	5.36	72.92	1.58	7.71	....	7,368	13,262
				3	....	44.48	55.52	....	.56	6.09	82.81	1.79	8.75	....	8,367	15,061
Thorp, 10 miles west of, sec. 33, T. 19 N., R. 16 E.; Joseph Wilson mine (run-of-mine coal taken from bunkers).	339	13269	B	1	7.69	39.63	36.51	16.17	.43	....	....	....	....	3.1	5,547	9,985
				2	....	42.93	39.55	17.52	.47	....	....	....	....	....	6,009	10,816
				3	....	52.05	47.95	....	.57	....	....	....	....	....	7,285	13,113
LEWIS COUNTY.																
Mendota; Mendota No. 1 mine, No. 3 bed (rib of second level; 10-foot bed).	339	12305	A	1	7.88	61.57	15.11	15.44	.29	6.73	58.92	.50	18.12	3.7	6,622	11,920
				2	....	66.83	16.41	16.76	.31	6.35	63.96	.54	12.08	....	7,188	12,938
				3	....	80.28	19.72	....	.37	7.63	76.84	.65	14.51	....	8,635	15,543
Same (rib in south level, 10-foot bed)	339	14084	A	1	3.18	80.47	12.04	4.31	.28	....	....	....	....	.4	....	....
				2	....	83.11	12.44	4.45	.29	....	....	....	....	....	....	....
				3	....	86.98	13.02	....	.30	....	....	....	....	....	....	....
Morton, 2 miles southeast of, SW. ¼ SW. ¼ sec. 12, T. 12 N., R. 4 E.; prospect, Edlund bed (4 feet from surface, 4-foot cut).	340	*12563	B	1	12.62	28.59	36.89	21.90	.73	....	....	....	....	5.1	....	....
				2	....	32.72	42.22	25.06	.84	....	....	....	....	....	....	....
				3	....	43.66	56.34	....	1.12	....	....	....	....	....	....	....
2 miles east of, SW. ¼ sec. 6, T. 12 N., R. 5 E.; prospect (in entry, 20 feet from entry mouth, 2-foot 10-inch bed, 2-foot cut).	340	*12564	B	1	8.02	22.74	53.24	16.00	.67	....	....	....	....	4.1	....	....
				2	....	24.72	57.88	17.40	.73	....	....	....	....	....	....	....
				3	....	29.93	70.07	....	.88	....	....	....	....	....	....	....
4 miles north of, sec. 14, T. 13 N., R. 4 E.; prospect (about 60 feet from entry mouth, 14+-foot bed, 6+-foot cut).	341	12565	B	1	11.84	8.40	57.30	22.46	.79	....	....	....	....	6.2	5,384	9,691
				2	....	9.53	64.99	25.48	.90	....	....	....	....	....	6,107	10,993
				3	....	12.79	87.21	....	1.21	....	....	....	....	....	8,195	14,751
PIERCE COUNTY.																
Ashford; NW. ¼ sec. 15, T. 15 N., R. 6 E.; prospect, Misqualy Chief bed (in entry, 100 feet from mouth of entry, 13-foot 4-inch bed, 11-foot 9-inch cut).	341	12581	B	1	5.81	15.28	54.68	24.23	0.41	....	....	....	....	3.6	5,782	10,408
				2	....	16.22	58.06	25.72	.44	....	....	....	....	....	6,139	11,050
				3	....	21.84	78.16	....	.59	....	....	....	....	....	8,265	14,877
Fairfax, 2 miles south of; SW. ¼ sec. 2, T. 17 N., R. 6 E.; prospect, Montezuma bed (face of entry, 45 feet from mouth of entry, 9-foot 7-inch bed, 4-foot cut).	342	12478	B	1	3.57	20.60	41.93	33.90	.55	....	....	....	....	2.3	3,455	6,219
				2	....	21.36	43.49	35.15	.57	....	....	....	....	....	3,583	6,449
				3	....	32.94	67.06	....	.88	....	....	....	....	....	5,525	9,945

½ mile south of; NE. ¼ NW. ¼ sec. 34, T. 18 N., R. 6 E.; prospect No. 1, No. 1 bed (in entry, 35 feet from mouth of entry, 4-foot 1-inch bed, 2-foot 10-inch cut).	342	12496	B	1	4.75	26.37	60.82	8.06	1.13	......	......	......	......	4.0	7,574	13,638
				2	......	27.69	63.85	8.46	1.19	......	......	......	......	......	7,952	14,314
				3	......	30.25	69.75	......	1.30	......	......	......	......	......	8,687	15,637
½ mile south of; NE. ¼ NW. ¼ sec. 34, T. 18 N., R. 6 E.; prospect No. 2, No. 2 bed (in entry, 35 feet from mouth of entry, 5-foot 5-inch bed, 2-foot 11-inch cut).	342	12495	B	1	2.56	24.81	52.79	19.84	.68	......	......	......	......	1.7	6,586	11,855
				2	......	25.46	54.18	20.36	.70	......	......	......	......	......	6,759	12,166
				3	......	31.97	68.03	......	.88	......	......	......	......	......	8,487	15,277
Wilkeson; Gale Creek mine, Queen bed (face of north gangway 1, off new slope, 3-foot 8½-inch bed, 3-foot 3¾-inch cut).	343	W31921	A	1	2.4	35.7	52.1	9.8	.85	......	......	......	......	......	7,556	13,600
				2	......	36.6	53.4	10.0	.90	......	......	......	......	......	7,744	13,940
				3	......	40.7	59.3	......	1.00	......	......	......	......	......	8,606	15,490
Same (position, bed, and cut same as No. W31921).	343	W31922	A	1	2.4	35.8	51.6	10.2	.90	......	......	......	......	......	7,500	13,500
				2	......	36.7	52.9	10.4	.95	......	......	......	......	......	7,683	13,830
				3	......	41.0	59.0	......	1.06	......	......	......	......	......	8,578	15,440
Same (breast 16 at face of counter No. 1 north, off new slope, 3-foot 7½-inch bed and cut).	343	W31923	A	1	2.6	35.4	51.7	10.3	.80	......	......	......	......	......	7,461	13,430
				2	......	36.3	53.1	10.6	.85	......	......	......	......	......	7,661	13,790
				3	......	40.6	59.4	......	.95	......	......	......	......	......	8,567	15,420
Same (position, bed, and cut same as No. W31923).	343	W31924	A	1	2.6	35.3	52.1	10.0	.85	......	......	......	......	......	7,511	13,520
				2	......	36.2	53.5	10.3	.90	......	......	......	......	......	7,711	13,880
				3	......	40.4	59.6	......	1.00	......	......	......	......	......	8,594	15,470
Same (pillar of breast 10, off north gangway 1, off new slope, 3-foot 9-inch bed, 3-foot 5½-inch cut).	343	W31925	A	1	2.9	35.7	51.8	9.6	.65	......	......	......	......	......	7,517	13,530
				2	......	36.8	53.3	9.9	.70	......	......	......	......	......	7,739	13,930
				3	......	40.8	59.2	......	.78	......	......	......	......	......	8,599	15,460
Same (position, bed, and cut same as No. W31925).	343	W31926	A	1	2.7	35.8	51.9	9.6	.70	......	......	......	......	......	7,528	13,550
				2	......	36.8	53.3	9.9	.70	......	......	......	......	......	7,733	13,920
				3	......	40.8	59.2	......	.78	......	......	......	......	......	8,583	15,450
Same (left air course 1 of new slope, below north gangway 1, 3-foot 8½-inch bed, 3-foot ½-inch cut).	343	W32106	A	1	2.4	34.9	52.4	10.3	1.00	......	......	......	......	......	7,411	13,340
				2	......	35.7	53.7	10.6	1.05	......	......	......	......	......	7,589	13,660
				3	......	39.9	60.1	......	1.17	......	......	......	......	......	8,489	15,280
Same (pillar of first crosscut on breast 14, off north gangway 1, off new slope, 3-foot 7½-inch bed, 3-foot 4-inch cut).	343	W32107	A	1	2.6	35.5	53.1	8.8	.95	......	......	......	......	......	7,583	13,650
				2	......	36.4	54.6	9.0	1.00	......	......	......	......	......	7,783	14,010
				3	......	40.0	60.0	......	1.10	......	......	......	......	......	8,550	15,390
Same (face of crosscut on new slope opposite south gangway 2, 4-foot 8-inch bed, 3-foot 9-inch cut).	343	W32108	A	1	3.5	34.8	52.2	9.5	.90	......	......	......	......	......	7,422	13,360
				2	......	36.0	54.2	9.8	.95	......	......	......	......	......	7,689	13,840
				3	......	39.9	60.1	......	1.05	......	......	......	......	......	8,522	15,340
Same (composite of samples W32106–W32108 and W31921–W31926).	343	14390	A	1	1.91	35.13	53.08	9.88	.86	5.72	75.10	2.19	6.25	......	7,549	13,588
				2	......	35.82	54.11	10.07	.88	5.62	76.56	2.23	4.64	......	7,696	13,853
				3	......	39.83	60.17	......	.98	6.25	85.13	2.48	5.16	......	8,558	15,404
Same (from 4 cars, washed)	343	W32104	C	1	1.4	24.6	64.1	9.9	.85	......	......	......	......	......	7,594	13,670
				2	......	25.0	65.0	10.0	.85	......	......	......	......	......	7,706	13,870
				3	......	27.8	72.2	......	.94	......	......	......	......	......	8,561	15,410
Same (from same cars as No. W32104)	343	W32105	C	1	1.4	35.0	53.0	10.6	1.10	......	......	......	......	......	7,500	13,500
				2	......	35.5	53.7	10.8	1.10	......	......	......	......	......	7,606	13,690
				3	......	39.8	60.2	......	1.23	......	......	......	......	......	8,528	15,350
Same (from 4 cars, washed)	343	W32145	C	1	1.9	34.6	52.4	11.1	.65	......	......	......	......	......	7,433	13,380
				2	......	35.3	53.4	11.3	.65	......	......	......	......	......	7,578	13,640
				3	......	39.8	60.2	......	.73	......	......	......	......	......	8,544	15,380
Same (from same cars as No. W32145)	343	W32146	C	1	1.9	34.7	51.6	11.8	.90	......	......	......	......	......	7,339	13,210
				2	......	35.4	52.6	12.0	.90	......	......	......	......	......	7,478	13,460
				3	......	40.2	59.8	......	1.02	......	......	......	......	......	8,500	15,300

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample. Laboratory No.	Sample. Kind.	Sample. Condition.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Air-drying loss.	Calorific value. Calories.	Calorific value. British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WASHINGTON—Continued.																
PIERCE COUNTY—continued.																
Wilkeson; Gale Creek mine, Queen bed (from 4 cars, washed).	343	W32147	C	1	2.7	34.2	52.4	10.7	.88						7,390	13,300
				2	......	35.1	53.9	11.0	.90						7,594	13,670
				3	......	39.4	60.6	......	1.01						8,533	15,360
Same (from 4 cars, washed)	343	W32158	C	1	3.6	33.3	51.2	11.9	.90						7,280	13,100
				2	......	34.5	53.2	12.3	.95						7,506	13,510
				3	......	39.3	60.7	......	1.08						8,561	15,410
Same (from same cars as No. W32158)	343	W32159	C	1	3.6	33.7	51.1	11.6	.90						7,220	13,000
				2	......	35.0	53.0	12.0	.95						7,522	13,540
				3	......	39.8	60.2	......	1.08						8,500	15,300
Same (from 4 cars, washed)	343	W32160	C	1	3.5	34.6	50.9	11.0	.95						7,317	13,170
				2	......	35.9	52.7	11.4	1.00						7,581	13,650
				3	......	40.5	59.5	......	1.13						8,561	15,410
Same (from same cars as No. W32160)	343	W32161	C	1	3.5	34.7	50.8	11.0	.82						7,278	13,100
				2	......	36.0	52.6	11.4	.85						7,594	13,670
				3	......	40.6	59.4	......	.96						8,572	15,430
Same (from 4 cars, washed)	343	W32211	C	1	3.7	34.2	51.2	10.9	.90						7,311	13,160
				2	......	35.5	53.2	11.3	.95						7,594	13,670
				3	......	40.0	60.0	......	1.07						8,561	15,410
Same (from same cars as No. W32211)	343	W32212	C	1	3.4	34.7	51.3	10.6	.85						7,322	13,180
				2	......	35.9	53.1	11.0	.90						7,561	13,610
				3	......	40.3	59.7	......	1.01						8,522	15,340
Same (from 3 cars, washed)	343	W32213	C	1	3.0	34.7	51.7	10.6	.90						7,344	13,220
				2	......	35.8	53.3	10.9	.95						7,579	13,640
				3	......	40.2	59.8	......	1.07						8,500	15,300
Same (from same cars as No. W32213)	343	W32214	C	1	3.0	34.6	51.9	10.5	.85						7,383	13,290
				2	......	35.7	53.5	10.8	.90						7,611	13,700
				3	......	40.0	60.0	......	1.01						8,533	15,360
WEST VIRGINIA.																
BRAXTON COUNTY.																
Braxton; Braxton mine, Pittsburgh bed (in room, about 325 feet southeast of mine mouth, 5-foot 3-inch bed and cut).	344	13556	B	1	2.83	40.90	47.59	8.68	3.40					1.9	7,339	13,210
				2	......	42.09	48.98	8.93	3.50						7,599	13,678
				3	......	46.22	53.78	......	3.84						8,342	15,016

BROOKE COUNTY.																
Colliers, 1 mile west of: Lewis-Finley No. 1 mine, Pittsburgh bed (room 1, off butt entry 6, off main entry, 4-foot 7½-inch bed, 3-foot 6-inch cut).	345	15671	B	1	4.58	35.36	54.05	6.01	1.28	5.28	73.81	1.55	12.07	2.6	7,352	13,234
				2	......	37.06	56.64	6.30	1.34	5.00	77.35	1.62	8.39	......	7,705	13,869
				3	......	39.55	60.45	......	1.43	5.34	82.55	1.73	8.95	......	8,223	14,801
Same (room 77, off entry 10, side No. 2, 5,800 feet northwest of mine mouth, 4-foot 8-inch bed, 4-foot ½-inch cut).	345	15672	B	1	4.13	36.62	53.26	5.99	2.07	......	......	......	......	1.5	7,446	13,403
				2	......	38.20	55.55	6.25	2.16	......	......	......	......	......	7,767	13,981
				3	......	40.75	59.25	......	2.30	......	......	......	......	......	8,285	14,913
FAYETTE COUNTY.																
Caperton; Sewell mine, Sewell bed (room turned off at face of drainage entry of Sugar Camp No. 3 workings, 4-foot bed and cut).	345	14344	A	1	3.99	24.29	68.78	2.94	.56	......	......	......	......	3.0	8,050	14,490
				2	......	25.30	71.64	3.06	.58	......	......	......	......	......	8,385	15,093
				3	......	26.10	73.90	......	.60	......	......	......	......	......	8,650	15,570
Same (at last break-through in third right air course of Sugar Camp No. 1 workings, 2-foot 9-inch bed, 2-foot 5-inch cut).	345	14345	A	1	4.70	23.81	69.63	1.86	.50	......	......	......	......	3.7	8,114	14,605
				2	......	24.98	73.07	1.95	.52	......	......	......	......	......	8,514	15,325
				3	......	25.48	74.52	......	.53	......	......	......	......	......	8,683	15,629
Same (face of right entry 13, Old Hill workings, 5,000 feet northeast of mine mouth, 4-foot 2½-inch bed, 4-foot cut).	345	14346	A	1	3.28	24.37	70.44	1.91	.53	......	......	......	......	2.2	8,218	14,792
				2	......	25.20	72.83	1.97	.55	......	......	......	......	......	8,497	15,295
				3	......	25.71	74.29	......	.56	......	......	......	......	......	8,668	15,602
Same (composite of samples 14344, 14345, and 14346).	346	14347	A	1	3.97	23.84	69.97	2.22	.56	5.08	83.37	1.62	7.15	3.0	8,116	14,609
				2	......	24.82	72.87	2.31	.58	4.83	86.81	1.69	3.78	......	8,451	15,212
				3	......	25.41	74.59	......	.59	4.94	88.86	1.73	3.88	......	8,650	15,570
Same (pillar at last room off cross entry 11, Old Hill workings, 3-foot 8½-inch bed and cut).	345	14348	A	1	3.49	23.75	70.09	2.67	.57	......	......	......	......	2.5	8,137	14,647
				2	......	24.61	72.62	2.77	.59	......	......	......	......	......	8,432	15,178
				3	......	25.31	74.69	......	.61	......	......	......	......	......	8,672	15,610
Same (on pillar of right entry 2, Sugar Camp No. 2 workings, 4-foot 1-inch bed, 3-foot 11-inch cut).	345	14349	A	1	2.89	25.47	69.28	2.36	.53	......	......	......	......	2.0	8,235	14,823
				2	......	26.23	71.34	2.43	.55	......	......	......	......	......	8,480	15,264
				3	......	26.88	73.12	......	.56	......	......	......	......	......	8,691	15,644
Same (composite of samples 14348 and 14349).....	346	14350	A	1	3.22	24.54	69.70	2.54	.55	5.16	83.80	1.67	6.28	2.3	8,170	14,706
				2	......	25.36	72.02	2.62	.57	4.96	86.59	1.73	3.53	......	8,442	15,196
				3	......	26.04	73.96	......	.59	5.09	88.92	1.78	3.62	......	8,669	15,604
Dunloop; Dunn Loop No. 2 mine, Sewell bed (at last break-through to the right on main entry 5; 500 feet northeast of mouth of main entry 5; 5-foot 8½-inch bed and cut).	346	14383	A	1	3.75	22.11	71.95	2.19	.58	......	......	......	......	2.7	......	......
				2	......	22.97	74.75	2.28	.60	......	......	......	......	......	......	......
				3	......	23.51	76.49	......	.61	......	......	......	......	......	......	......
Same (face of room 20, off right entry 8, off main entry 4; 1,600 feet southeast of mouth of main entry 4; 5-foot 7-inch bed and cut.)	346	14384	A	1	3.62	21.01	72.16	3.21	.80	......	......	......	......	2.7	......	......
				2	......	21.80	74.87	3.33	.83	......	......	......	......	......	......	......
				3	......	22.55	77.45	......	.86	......	......	......	......	......	......	......
Same (face of room 2, first crosscut off first left air course off main entry 6; 1,200 feet east of mouth of main entry 6; 5-foot 8-inch bed and cut).	346	14385	A	1	3.31	21.33	72.87	2.49	.44	......	......	......	......	2.3	......	......
				2	......	22.06	75.36	2.58	.46	......	......	......	......	......	......	......
				3	......	22.64	77.36	......	.47	......	......	......	......	......	......	......
Same (composite of samples 14383, 14384, and 14385).	346	14386	A	1	3.58	21.07	72.75	2.60	.64	5.01	84.38	1.65	5.72	2.6	8,195	14,751
				2	......	21.85	75.45	2.70	.66	4.78	87.51	1.71	2.64	......	8,499	15,298
				3	......	22.46	77.54	......	.68	4.91	89.93	1.76	2.72	......	8,734	15,721
Same (face of room 5, off the air course of main entry 3; 500 feet southeast of mouth of main entry 3; 5-foot 2-inch bed, 61-inch cut).	346	14387	A	1	3.95	20.61	72.94	2.50	.53	......	......	......	......	2.8	......	......
				2	......	21.46	75.94	2.60	.55	......	......	......	......	......	......	......
				3	......	22.03	77.97	......	.56	......	......	......	......	......	......	......
Same (pillar 17 of main entry 6; 1,040 feet southeast of mouth of main entry 6; 5-foot 10-inch bed and cut).	346	14388	A	1	3.54	20.45	73.02	2.99	.55	......	......	......	......	2.6	......	......
				2	......	21.20	75.70	3.10	.57	......	......	......	......	......	......	......
				3	......	21.88	78.12	......	.59	......	......	......	......	......	......	......
Same (composite of samples 14387 and 14388).....	346	14389	A	1	3.77	21.00	72.46	2.77	.55	4.91	84.06	1.66	6.05	2.7	8,157	14,683
				2	......	21.82	75.30	2.88	.57	4.67	87.36	1.73	2.79	......	8,477	15,259
				3	......	22.47	77.53	......	.59	4.81	89.95	1.78	2.87	......	8,729	15,712

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WASHINGTON—Continued.																
PIERCE COUNTY—continued.																
Wilkeson; Gale Creek mine, Queen bed (from 4 cars, washed).	343	W32147	C	1	2.7	34.2	52.4	10.7	.85	......	......	......	......	......	7,389	13,300
				2	......	35.1	53.9	11.0	.90	......	......	......	......	......	7,594	13,670
				3	......	39.4	60.6	......	1.01	......	......	......	......	......	8,533	15,360
Same (from 4 cars, washed)	343	W32158	C	1	3.6	33.3	51.2	11.9	.90	......	......	......	......	......	7,239	13,030
				2	......	34.5	53.2	12.3	.95	......	......	......	......	......	7,506	13,510
				3	......	39.3	60.7	......	1.08	......	......	......	......	......	8,561	15,410
Same (from same cars as No. W32158)	343	W32159	C	1	3.6	33.7	51.1	11.6	.90	......	......	......	......	......	7,250	13,050
				2	......	35.0	53.0	12.0	.95	......	......	......	......	......	7,522	13,540
				3	......	39.8	60.2	......	1.08	......	......	......	......	......	8,550	15,390
Same (from 4 cars, washed)	343	W32160	C	1	3.5	34.6	50.9	11.0	.95	......	......	......	......	......	7,317	13,170
				2	......	35.9	52.7	11.4	1.00	......	......	......	......	......	7,583	13,650
				3	......	40.5	59.5	......	1.13	......	......	......	......	......	8,561	15,410
Same (from same cars as No. W32160)	343	W32161	C	1	3.5	34.7	50.8	11.0	.80	......	......	......	......	......	7,328	13,190
				2	......	36.0	52.6	11.4	.85	......	......	......	......	......	7,594	13,670
				3	......	40.6	59.4	......	.96	......	......	......	......	......	8,572	15,430
Same (from 4 cars, washed)	343	W32211	C	1	3.7	34.2	51.2	10.9	.90	......	......	......	......	......	7,311	13,160
				2	......	35.5	53.2	11.3	.95	......	......	......	......	......	7,594	13,670
				3	......	40.0	60.0	......	1.07	......	......	......	......	......	8,561	15,410
Same (from same cars as No. W32211)	343	W32212	C	1	3.4	34.7	51.3	10.6	.85	......	......	......	......	......	7,322	13,180
				2	......	35.9	53.1	11.0	.90	......	......	......	......	......	7,583	13,650
				3	......	40.3	59.7	......	1.01	......	......	......	......	......	8,522	15,340
Same (from 3 cars, washed)	343	W32213	C	1	3.0	34.7	51.7	10.6	.90	......	......	......	......	......	7,344	13,220
				2	......	35.8	53.3	10.9	.95	......	......	......	......	......	7,572	13,630
				3	......	40.2	59.8	......	1.07	......	......	......	......	......	8,500	15,300
Same (from same cars as No. W32213)	343	W32214	C	1	3.0	34.6	51.9	10.5	.85	......	......	......	......	......	7,383	13,290
				2	......	35.7	53.5	10.8	.90	......	......	......	......	......	7,611	13,700
				3	......	40.0	60.0	......	1.01	......	......	......	......	......	8,533	15,360
WEST VIRGINIA.																
BRAXTON COUNTY.																
Braxton; Braxton mine, Pittsburgh bed (in room, about 325 feet southeast of mine mouth, 5-foot 3-inch bed and cut).	344	13556	B	1	2.83	40.90	47.59	8.68	3.40	......	......	......	......	1.2	7,382	13,288
				2	......	42.09	48.98	8.93	3.50	......	......	......	......	......	7,597	13,675
				3	......	46.22	53.78	......	3.84	......	......	......	......	......	8,342	15,016

Kay Moor, ¾ mile south of; Kay Moor No. 1 mine, Sewell bed (face of room 1, off left entry 3, off third main entry, 4,700 feet south of mine mouth, 3-foot 8½-inch bed and cut).	349	14294	A	1	3.00	25.22	68.28	3.50	.55	......	......	......	......	2.1	......	......
				2	......	26.00	70.39	3.61	.57	......	......	......	......	......	......	......
				3	......	26.98	73.02	......	.59	......	......	......	......	......	......	......
Same (face of right entry 1½, off left entry 1, off Buffalo entry, 3,300 feet southeast of mine mouth, 3-foot 10⅜-inch bed and cut).	349	14295	A	1	3.41	25.09	69.17	2.33	.60	......	......	......	......	2.4	......	......
				2	......	25.98	71.61	2.41	.62	......	......	......	......	......	......	......
				3	......	26.62	73.38	......	.64	......	......	......	......	......	......	......
Same (face of left entry 1, off right entry 9, 3,300 feet west of mine mouth, 3-foot 6½-inch bed and cut).	349	14296	A	1	3.11	26.03	67.32	3.54	.60	......	......	......	......	2.1	......	......
				2	......	26.87	69.48	3.65	.62	......	......	......	......	......	......	......
				3	......	27.89	72.11	......	.64	......	......	......	......	......	......	......
Same (face of west entry 11, 3,600 feet southwest of mine mouth, 3-foot 3-inch bed and cut).	349	14297	A	1	3.12	25.58	69.02	2.28	.54	......	......	......	......	2.2	......	......
				2	......	26.40	71.25	2.35	.56	......	......	......	......	......	......	......
				3	......	27.04	72.96	......	.57	......	......	......	......	......	......	......
Same (composite of samples 14294–14297).........	349	14298	A	1	3.17	25.11	68.81	2.91	.52	5.09	82.59	1.63	7.26	2.2	8,102	14,584
				2	......	25.93	71.06	3.01	.54	4.89	85.29	1.68	4.59	......	8,367	15,061
				3	......	26.73	73.27	......	.56	5.04	87.93	1.73	4.74	......	8,626	15.527
Same (pillar between rooms 3 and 4, off right entry 1, off main entry 7, 3-foot 4-inch bed and cut).	349	14299	A	1	3.17	25.24	67.89	3.70	.51	4.97	82.05	1.67	7.10	2.2	8,055	14,499
				2	......	26.07	70.11	3.82	.53	4.77	84.73	1.72	4.43	......	8,318	14,972
				3	......	27.10	72.90	......	.55	4.96	88.09	1.79	4.61	......	8,648	15,566
south of; Kay Moor No. 2 mine, Sewell bed (face of left entry 3, off main entry, 3-foot bed and cut).	350	14401	A	1	2.79	26.25	68.09	2.87	.50	......	......	......	......	1.8	......	......
				2	......	27.00	70.05	2.95	.51	......	......	......	......	......	......	......
				3	......	27.82	72.18	......	.53	......	......	......	......	......	......	......
Same (face of room 9, off left entry 2, 2-foot 11½-inch bed and cut).	350	14402	A	1	3.02	26.00	68.60	2.38	.50	......	......	......	......	1.9	......	......
				2	......	26.81	70.74	2.45	.52	......	......	......	......	......	......	......
				3	......	27.48	72.52	......	.53	......	......	......	......	......	......	......
Same (face of room 9, off left entry 1; 150 feet from the entry, 3-foot ½-inch bed and cut).	350	14403	A	1	3.11	25.67	67.05	4.17	.56	......	......	......	......	2.0	......	......
				2	......	26.49	69.21	4.30	.58	......	......	......	......	......	......	......
				3	......	27.68	72.32	......	.61	......	......	......	......	......	......	......
Same (composite of samples 14401, 14402, and 14403).	350	14404	A	1	3.03	25.73	68.11	3.13	.57	5.14	82.73	1.65	6.78	1.9	8,114	14,605
				2	......	26.53	70.24	3.23	.59	4.95	85.31	1.70	4.22	......	8,367	15,061
				3	......	27.42	72.58	......	.61	5.12	88.16	1.76	4.35	......	8,646	15,563
South Nuttal; Brown mine, Sewell bed (face of room 2, off Hill entry, 3-foot 6-inch bed, 2-foot 10-inch cut).	350	10618	A	1	3.63	23.70	70.10	2.57	.70	......	......	......	......	2.8	......	......
				2	......	24.59	72.74	2.67	.73	......	......	......	......	......	......	......
				3	......	25.26	74.74	......	.75	......	......	......	......	......	......	......
Same (rib of Lockett heading, between rooms 1 and 2, 2,000 feet from entry mouth, 3-foot 9½-inch bed and cut).	350	10619	A	1	3.36	24.88	68.62	3.14	.68	......	......	......	......	2.5	......	......
				2	......	25.75	71.00	3.25	.70	......	......	......	......	......	......	......
				3	......	26.62	73.38	......	.72	......	......	......	......	......	......	......
Same (neck of room 1, off right entry 6, off Wheeler entry, 3-foot 5-inch bed and cut).	350	10620	A	1	3.81	23.32	70.16	2.71	.52	......	......	......	......	3.0	......	......
				2	......	24.24	72.94	2.82	.54	......	......	......	......	......	......	......
				3	......	24.94	75.06	......	.56	......	......	......	......	......	......	......
Same (neck of room 4, off left entry 2, off entry 18, 3-foot 6-inch bed and cut).	350	10621	A	1	3.45	23.91	70.39	2.25	.55	......	......	......	......	2.6	......	......
				2	......	24.76	72.91	2.33	.57	......	......	......	......	......	......	......
				3	......	25.35	74.65	......	.58	......	......	......	......	......	......	......
Same (left rib near face of entry 18, 3-foot 5½-inch bed and cut).	350	10622	A	1	3.32	24.92	69.35	2.41	.51	......	......	......	......	2.5	......	......
				2	......	25.77	71.74	2.49	.53	......	......	......	......	......	......	......
				3	......	26.43	73.57	......	.54	......	......	......	......	......	......	......
Same (composite of samples 10618–10622).........	351	10623	A	1	3.51	24.76	69.00	2.73	.58	5.17	83.06	1.57	6.89	2.7	8,146	14,663
				2	......	25.66	71.51	2.83	.60	4.95	86.08	1.63	3.91	......	8,443	15,197
				3	......	26.41	73.59	......	.62	5.09	88.58	1.68	4.03	......	8,689	15,640

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WEST VIRGINIA—Continued.																
FAYETTE COUNTY—continued.																
Thayer, Ephraims Creek (Buffalo) mine, Fire Creek bed (face of room 5, off right entry 5, off Slater entry, 3-foot 6-inch bed and cut).	351	10629	A	1	3.17	18.46	70.86	7.51	1.07	4.84	79.07	1.56	5.95	2.5	7,775	13,995
				2	......	19.06	73.18	7.76	1.10	4.64	81.66	1.61	3.23	......	8,029	14,452
				3	......	20.66	79.34	......	1.19	5.03	88.53	1.75	3.50	......	8,704	15,667
GREENBRIER COUNTY.																
Richwood, 9 miles southeast of; Spruce Knob mine, Sewell bed (in mine, 1,500 feet southwest of mine mouth; 4-foot 10-inch bed; 4-foot 1-inch cut).	352	13547	B	1	3.91	26.20	64.09	5.80	.62	5.00	79.33	1.59	7.66	3.1	7,810	14,058
				3	......	27.27	66.69	6.04	.65	4.76	82.56	1.65	4.34	......	8,128	14,630
				3	......	29.02	70.98	......	.69	5.07	87.87	1.76	4.61	......	8,651	15,572
M'DOWELL COUNTY.																
Algoma, 1 mile east of; Piney mine, Pocahontas No. 3 bed (face of main entry, 6-foot 1-inch bed, 5-foot 10-inch cut).	352	14154	A	1	2.50	17.84	74.30	5.36	.52	......	......	......	......	1.8	......	......
				2	......	18.30	76.20	5.50	.53	......	......	......	......	......	......	......
				3	......	19.37	80.63	......	.56	......	......	......	......	......	......	......
Same (face of room 14, off cross entry 10, 5-foot 3-inch bed, 5-foot 1½-inch cut).	352	14155	A	1	2.60	18.59	74.19	4.62	.47	......	......	......	......	1.9	......	......
				2	......	19.09	76.17	4.74	.48	......	......	......	......	......	......	......
				3	......	20.04	79.96	......	.50	......	......	......	......	......	......	......
Same (face of room 30, off cross entry 8, 5-foot 6-inch bed, 5-foot 3-inch cut).	352	14156	A	1	2.70	17.87	75.12	4.31	.44	......	......	......	......	2.0	......	......
				2	......	18.36	77.21	4.43	.45	......	......	......	......	......	......	......
				3	......	19.21	80.79	......	.47	......	......	......	......	......	......	......
Same (composite of samples 14154, 14155, and 14156)	352	14157	A	1	2.58	18.10	74.58	4.74	.47	4.52	84.25	1.17	4.85	1.9	8,086	14,555
				2	......	18.58	76.55	4.87	.48	4.34	86.48	1.20	2.63	......	8,300	14,940
				3	......	19.53	80.47	......	.50	4.56	90.91	1.26	2.77	......	8,725	15,705
Same (pillar of room 15, off cross entry 5, 6-foot 7-inch bed, 6-foot 4-inch cut).	352	14158	A	1	2.80	17.61	74.41	5.18	.64	......	......	......	......	2.1	......	......
				2	......	18.12	76.55	5.33	.66	......	......	......	......	......	......	......
				3	......	19.14	80.86	......	.70	......	......	......	......	......	......	......
Same (rib of room 33, off cross entry 7, 5-foot 6-inch bed, 5-foot 3-inch cut).	352	14159	A	1	2.63	18.09	74.74	4.54	.47	......	......	......	......	1.9	......	......
				2	......	18.58	76.76	4.66	.48	......	......	......	......	......	......	......
				3	......	19.49	80.51	......	.50	......	......	......	......	......	......	......
Same (pillar of room 15, off cross entry 6, 6-foot 4-inch bed, 6-foot ½-inch cut).	352	14160	A	1	2.39	17.71	75.61	4.29	.69	......	......	......	......	1.7	......	......
				2	......	18.14	77.46	4.40	.71	......	......	......	......	......	......	......
				3	......	18.97	81.03	......	.74	......	......	......	......	......	......	......

Same (pillar of room 8, off cross entry 3, 6-foot 7-inch bed, 6-foot 4-inch cut).	352	14161	A	1	2.75	17.37	75.51	4.37	.59	....	....	....	....	2.1	....	....
				2	....	17.86	77.65	4.49	.61	....	....	....	....	....	....	....
				3	....	18.70	81.30	....	.64	....	....	....	....	....	....	....
Same (composite of samples 14158–14161).........	353	14162	A	1	2.63	17.68	75.13	4.56	.63	4.44	84.72	1.22	4.43	2.0	8,096	14,573
				2	....	18.16	77.16	4.68	.65	4.26	87.01	1.25	2.15	....	8,315	14,967
				3	....	19.05	80.95	....	.68	4.47	91.28	1.31	2.26	....	8,723	15,701
Big Four; Cirrus No. 2 mine, Pocahontas No 3 bed (at the break-through near face of main heading, 2,850 feet south of slope mouth, 5-foot 7-inch bed, 5-foot ½-inch cut).	353	14218	A	1	2.31	17.05	76.18	4.46	.58	....	....	....	....	1.7	....	....
				2	....	17.45	77.98	4.57	.59	....	....	....	....	....	....	....
				3	....	18.29	81.71	....	.62	....	....	....	....	....	....	....
Same (pocket 30 feet from face of south entry 6, 1,500 feet southwest of slope mouth, 5-foot 5½-inch bed, 5-foot 2½-inch cut).	353	14219	A	1	2.28	17.72	75.29	4.71	.61	....	....	....	....	1.6	....	....
				2	....	18.13	77.05	4.82	.62	....	....	....	....	....	....	....
				3	....	19.05	80.95	....	.65	....	....	....	....	....	....	....
Same (face of room 4, off south heading 3; 2,850 feet south of slope mouth, 5-foot 8-inch bed, 5-foot 2½-inch cut).	353	14220	A	1	2.54	17.53	75.71	4.22	.70	....	....	....	....	1.9	....	....
				2	....	17.99	77.68	4.33	.72	....	....	....	....	....	....	....
				3	....	18.80	81.20	....	.75	....	....	....	....	....	....	....
Same (face of east heading 6, 2,100 feet south of slope mouth, 5-foot 2½-inch bed, 4-foot 9-inch cut.)	353	14221	A	1	2.27	17.32	75.98	4.43	.58	....	....	....	....	1.6	....	....
				2	....	17.72	77.75	4.53	.59	....	....	....	....	....	....	....
				3	....	18.56	81.44	....	.62	....	....	....	....	....	....	....
Same (composite of samples 14218–14221)..........	353	14222	A	1	2.30	16.98	76.21	4.51	.66	4.36	85.00	1.20	4.27	1.7	8,131	14,636
				2	....	17.38	78.00	4.62	.68	4.20	87.00	1.23	2.27	....	8,322	14,980
				3	....	18.22	81.78	....	.71	4.40	91.21	1.29	2.39	....	8,725	15,705
Same; Pocahontas No. 4 bed (face of north entry 250 feet northwest of slope mouth; 4-foot 7½-inch bed, 4-foot 2½-inch cut).	353	14223	A	1	3.10	17.91	75.26	3.73	.55	4.50	84.02	1.17	6.03	2.5	8,180	14,724
				2	....	18.48	77.67	3.85	.57	4.29	86.71	1.21	3.37	....	8,442	15,196
				3	....	19.22	80.78	....	.59	4.46	90.18	1.26	3.51	....	8,780	15,804
Huger; Middle States mine, Pocahontas No. 3 bed (pillar between rooms 3 and 6, off north entry; 4-foot 7½-inch bed, 4-foot 6-inch cut).	354	14421	A	1	2.89	17.42	71.16	8.53	.83	....	....	....	....	2.2	....	....
				2	....	17.94	73.28	8.78	.85	....	....	....	....	....	....	....
				3	....	19.67	80.33	....	.93	....	....	....	....	....	....	....
Same, Pocahontas No. 4 bed (face of room 6, off second rock heading; 5-foot 1½-inch bed, 4-foot 10½-inch cut).	354	14416	A	1	1.28	18.13	73.57	7.02	.62	....	....	....	....	.5	....	....
				2	....	18.37	74.52	7.11	.63	....	....	....	....	....	....	....
				3	....	19.78	80.22	....	.68	....	....	....	....	....	....	....
Same (face of second right air course; 5-foot 5-inch bed, 5-foot cut).	354	14417	A	1	1.96	18.09	74.76	5.19	.58	....	....	....	....	1.2	....	....
				2	....	18.45	76.26	5.29	.59	....	....	....	....	....	....	....
				3	....	19.48	80.52	....	.62	....	....	....	....	....	....	....
Same (rib of last break-through on main diagonal entry; 5-foot 9½-inch bed, 5-foot 5-inch cut).	354	14418	A	1	1.64	17.65	75.89	4.82	.64	....	....	....	....	1.0	....	....
				2	....	17.94	77.16	4.90	.65	....	....	....	....	....	....	....
				3	....	18.86	81.14	....	.68	....	....	....	....	....	....	....
Same (face of room 4 off first west parallel heading; 5-foot 6½-inch bed, 5-foot 5-inch cut).	354	14419	A	1	1.53	18.14	73.46	6.87	.59	....	....	....	....	.9	....	....
				2	....	18.42	74.60	6.98	.60	....	....	....	....	....	....	....
				3	....	19.80	80.20	....	.64	....	....	....	....	....	....	....
Same (composite of samples 14416–14419)..........	354	14420	A	1	1.55	18.00	74.52	5.93	.61	4.38	83.70	1.32	4.06	.9	8,060	14,508
				2	....	18.28	75.70	6.02	.62	4.28	85.01	1.34	2.73	....	8,187	14,737
				3	....	19.45	80.55	....	.66	4.55	90.46	1.43	2.90	....	8,712	15,682
Same (pillar between rooms 8 and 9 off left entry 4 off main west heading; 4-foot 1-inch bed, 3-foot 11½-inch cut).	354	14422	A	1	1.64	17.87	75.02	5.47	.60	....	....	....	....	.9	....	....
				2	....	18.17	76.27	5.56	.61	....	....	....	....	....	....	....
				3	....	19.24	80.76	....	.65	....	....	....	....	....	....	....
Same (pillar between rooms 20 and 21 off second parallel entry off main diagonal heading; 5-foot 7½-inch bed, 5-foot 4-inch cut).	354	14423	A	1	1.58	18.03	74.12	6.27	.70	....	....	....	....	.9	....	....
				2	....	18.32	75.31	6.87	.71	....	....	....	....	....	....	....
				3	....	19.57	80.43	....	.76	....	....	....	....	....	....	....
Same (composite of samples 14421, 14422, and 14423).	354	14424	A	1	1.98	17.80	73.47	6.75	.71	4.49	82.64	1.20	4.21	1.3	7,958	14,324
				2	....	18.16	74.95	6.89	.72	4.36	84.31	1.22	2.50	....	8,119	14,614
				3	....	19.50	80.50	....	.77	4.68	90.55	1.31	2.69	....	8,720	15,696

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WEST VIRGINIA—Continued.																
M'DOWELL COUNTY—continued.																
Jed; Havaco (formerly Jed) mine, Pocahontas No. 3 bed (face of first butt left entry; 5-foot 1½-inch bed, 4-foot 9½-inch cut).	355	13775	A	1	2.08	16.39	76.60	4.93	.90	4.20	84.87	1.16	3.94	1.5	8,100	14,580
				2	....	16.74	78.23	5.03	.92	4.05	86.67	1.18	2.15	....	8,272	14,890
				3	....	17.63	82.37	....	.97	4.26	91.26	1.24	2.27	....	8,710	15,678
Jenkinjones; Pocahontas No. 6 mine, Pocahontas No. 3 bed (face of main heading, 250 feet west of mine mouth; 9-foot 6-inch bed, 8-foot 11½-inch cut).	356	14185	A	1	3.01	22.04	69.46	5.49	.49	....	....	....	....	2.4	....	....
				2	....	22.72	71.62	5.66	.51	....	....	....	....	....	....	....
				3	....	24.08	75.92	....	.54	....	....	....	....	....	....	....
Same (face of aircourse, 250 feet from mine mouth; 10-foot 2½-inch bed, 9-foot 2½-inch cut).	356	14186	A	1	3.66	21.78	70.64	3.92	.52	....	....	....	....	3.1	....	....
				2	....	22.61	73.32	4.07	.54	....	....	....	....	....	....	....
				3	....	23.57	76.43	....	.56	....	....	....	....	....	....	....
Same, (composite of samples 14185, 14186, and 14187).	356	14188	A	1	3.36	22.50	68.86	5.28	.52	4.83	82.51	1.22	5.64	2.7	7,983	14,369
				2	....	23.28	71.26	5.46	.54	4.62	85.38	1.26	2.74	....	8,261	14,870
				3	....	24.63	75.37	....	.57	4.89	90.31	1.33	2.90	....	8,738	15,729
½-mile south of; Pocahontas No. 6 B mine, Pocahontas No. 3 bed (face of main heading, 500 feet from mine mouth; 10-foot 6½-inch bed, 9-foot 5-foot cut).	356	14187	A	1	3.23	22.45	67.83	6.49	.48	....	....	....	....	2.6	....	....
				2	....	23.20	70.09	6.71	.50	....	....	....	....	....	....	....
				3	....	24.87	75.13	....	.54	....	....	....	....	....	....	....
Same (face of first right cross heading, 350 feet from mine mouth, 9-foot 4-inch bed, 8-foot 10-inch cut).	356	14189	A	1	3.27	22.88	69.36	4.49	.44	....	....	....	....	2.7	8,021	14,438
				2	....	23.65	71.71	4.64	.45	....	....	....	....	....	8,292	14,926
				3	....	24.80	75.20	....	.47	....	....	....	....	....	8,696	15,653
½-mile south of; Pocahontas No. 7 A mine, Pocahontas No. 3 bed (face of main heading, 120 feet from mine mouth, 7-foot 10-inch bed, 7-foot 1½-inch cut).	356	14190	A	1	4.09	22.07	69.05	4.79	.47	....	....	....	....	3.1	7,920	14,256
				2	....	23.01	72.00	4.99	.49	....	....	....	....	....	8,257	14,863
				3	....	24.22	75.78	....	.52	....	....	....	....	....	8,690	15,642
Leckie, ½ mile east of; Leckie No. 1 mine, Pocahontas No. 3 bed (face of room 1, off Monkey heading, 1,700 feet west of mine mouth, 8-foot 2½-inch bed, 7-foot 10-inch cut).	357	14271	A	1	3.53	17.95	75.48	3.04	.53	....	....	....	....	2.9	....	....
				2	....	18.61	78.24	3.15	.55	....	....	....	....	....	....	....
				3	....	19.21	80.79	....	.57	....	....	....	....	....	....	....
Same (face of Monkey heading, 1,900 feet west of mine mouth, 8-foot 1½-inch bed, 7-foot 6½-inch cut).	357	14272	A	1	3.39	18.56	74.81	3.24	.52	....	....	....	....	2.7	....	....
				2	....	19.21	77.44	3.35	.54	....	....	....	....	....	....	....
				3	....	19.88	80.12	....	.56	....	....	....	....	....	....	....
Same (face of Kick-back heading, 1,250 feet northwest of mine mouth, 7-foot 10½-inch bed, 7-foot 7½-inch cut).	357	14273	A	1	4.38	18.12	73.92	3.58	.52	....	....	....	....	3.3	....	....
				2	....	18.95	77.31	3.74	.54	....	....	....	....	....	....	....
				3	....	19.69	80.31	....	.56	....	....	....	....	....	....	....

Same (on chain pillar of right heading 1, 650 feet north of mine mouth, 7-foot 3-inch bed, 6-foot 10½-inch cut).	357	14274	A	1	4.03	18.50	74.46	3.01	.62	......	......	......	......	3.3	......	......
				2	......	19.28	77.58	3.14	.65	......	......	......	......	......	......	......
				3	......	19.90	80.10	......	.67	......	......	......	......	......	......	......
Same (pillar at mouth of room 1, off right heading 2, 950 feet northwest of mine mouth, 7-foot 4½-inch bed, 6-foot 11½-inch cut).	357	14275	A	1	3.68	18.51	74.75	3.06	.55	......	......	......	......	2.7	8,159	14,686
				2	......	19.22	77.60	3.18	.57	......	......	......	......		8,471	15,248
				3	......	19.85	80.15	......	.59	......	......	......	......	......	8,749	15,748
Same (composite of samples 14271–14275)	357	14276	A	1	3.81	18.27	74.70	3.22	.54	4.73	84.48	1.22	5.81	3.0	8,161	14,690
				2	......	18.99	77.66	3.35	.56	4.48	87.83	1.27	2.51	......	8,484	15,271
				3	......	19.65	80.35	......	.58	4.64	90.88	1.31	2.59	......	8,778	15,800
½-mile east of: Leckie No. 2 mine, Pocahontas No. 3 bed (face of room 17, off first right air course, 100 feet from outcrop, 7-foot 9-inch bed, 7-foot 4-inch cut).	357	14277	A	1	5.66	18.58	71.96	3.80	.48	......	......	......	......	4.4	......	......
				2	......	19.69	76.28	4.03	.51	......	......	......	......	......	......	......
				3	......	20.52	79.48	......	.53	......	......	......	......	......	......	......
Same (working face, 7-foot 6-inch bed, 7-foot 2-inch cut).	357	14278	A	1	3.17	18.83	75.05	2.95	.57	......	......	......	......	2.4	......	......
				2	......	19.45	77.50	3.05	.59	......	......	......	......	......	......	......
				3	......	20.06	79.94	......	.61	......	......	......	......	......	......	......
Same (face of main straight entry, 600 feet southeast of mine mouth, 8-foot bed, 7-foot 6-inch cut).	357	14279	A	1	4.16	18.65	74.52	2.67	.53	......	......	......	......	3.3	......	......
				2	......	19.46	77.75	2.79	.55	......	......	......	......	......	......	......
				3	......	20.02	79.98	......	.57	......	......	......	......	......	......	......
Same (face of room 5, off diagonal entry, 7-foot 11-inch bed, 7-foot 6-inch cut).	357	14280	A	1	3.75	18.10	75.03	3.12	.53	......	......	......	......	2.9	......	......
				2	......	18.81	77.95	3.24	.55	......	......	......	......	......	......	......
				3	......	19.44	80.56	......	.57	......	......	......	......	......	......	......
Same (face of left entry 1, 1,300 feet from mine mouth, 8-foot 4-inch bed, 7-foot 9½-inch cut).	357	14281	A	1	4.34	18.07	73.93	3.66	.53	......	......	......	......	3.5	......	......
				2	......	18.89	77.28	3.83	.55	......	......	......	......	......	......	......
				3	......	19.64	80.36	......	.57	......	......	......	......	......	......	......
Same (composite of samples 14277–14281)	358	14282	A	1	4.24	18.60	73.94	3.22	.52	4.76	83.32	1.22	6.96	3.3	8,127	14,629
				2	......	19.42	77.22	3.36	.54	4.48	87.01	1.27	3.34	......	8,487	15,277
				3	......	20.10	79.90	......	.56	4.64	90.04	1.31	3.45	......	8,782	15,808
Roderfield, 1¾ miles east of; Davy-Pocahontas No. 1 mine, War Creek bed (face of room 3, off entry 2, 6-foot 1-inch bed, 5-foot 5-inch cut).	358	14266	A	1	1.90	16.75	69.58	11.77	1.24	......	......	......	......	1.2	......	......
				2	......	17.07	70.93	12.00	1.26	......	......	......	......	......	......	......
				3	......	19.40	80.60	......	1.43	......	......	......	......	......	......	......
Same (face of entry 2, opposite room 9, 6-foot 10½-inch bed, 6-foot 1¼-inch cut).	358	14267	A	1	2.06	17.72	68.95	11.27	2.32	......	......	......	......	1.4	......	......
				2	......	18.09	70.40	11.51	2.37	......	......	......	......	......	......	......
				3	......	20.44	79.56	......	2.68	......	......	......	......	......	......	......
Same (face of entry 7, at mouth of room 15, 5-foot 8¼-inch bed, 4-foot 10¾-inch cut).	358	14268	A	1	2.83	16.85	70.20	10.12	1.77	......	......	......	......	2.1	......	......
				2	......	17.34	72.25	10.41	1.82	......	......	......	......	......	......	......
				3	......	19.35	80.65	......	2.03	......	......	......	......	......	......	......
Same (composite of samples 14266, 14267, and 14268).	358	14269	A	1	2.32	16.76	69.80	11.12	1.78	4.35	77.46	1.27	4.02	1.6	7,508	13,514
				2	......	17.16	71.46	11.38	1.82	4.19	79.30	1.30	2.01	......	7,687	13,837
				3	......	19.36	80.64	......	2.05	4.73	89.48	1.47	2.27	......	8,674	15,613
2 miles east of; Davy-Pocahontas No. 2 mine, Davy bed (face of room 5, off left entry 1, 500 feet southwest of mine mouth, 3-foot 8½-inch bed, 3-foot ½-inch cut).	359	14262	A	1	2.81	18.77	73.60	4.82	1.07	......	......	......	......	1.9	......	......
				2	......	19.31	75.73	4.96	1.10	......	......	......	......	......	......	......
				3	......	20.32	79.68	......	1.16	......	......	......	......	......	......	......
Same (face of first left air course, 600 feet southwest of mine mouth, 3-foot 11¾-inch bed, 3-foot 4½-inch cut).	359	14263	A	1	3.27	18.90	71.87	5.96	.69	......	......	......	......	2.4	......	......
				2	......	19.54	74.30	6.16	.71	......	......	......	......	......	......	......
				3	......	20.82	79.18	......	.76	......	......	......	......	......	......	......
Same (face of main heading, 600 feet west of mine mouth, 3-foot 6¾-inch bed, 2-foot 10½-inch cut).	359	14264	A	1	2.86	18.79	70.41	7.94	.84	......	......	......	......	1.7	......	......
				2	......	19.34	72.49	8.17	.86	......	......	......	......	......	......	......
				3	......	21.06	78.94	......	.94	......	......	......	......	......	......	......
Same (composite of samples 14262, 14263, and 14264).	359	14265	A	1	2.95	19.08	71.76	6.21	.86	4.57	81.53	1.38	5.45	2.0	7,903	14,225
				2	......	19.66	73.94	6.40	.89	4.37	84.01	1.42	2.91	......	8,143	14,657
				3	......	21.00	79.00	......	.95	4.67	89.76	1,52	3.10	......	8,700	15,660

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WEST VIRGINIA—Continued.																
M'DOWELL COUNTY—continued.																
Rolfe, 3 miles from North Fork; Rolfe mine, Pocahontas No. 3 bed (face of B-2 butt entry off B entry, 5,800 feet northwest of mine mouth, 5-foot 3-inch bed, 4-foot 11-inch cut).	360	14394	A	1	2.63	18.08	73.07	6.22	.48	......	......	......	......	1.8	......	......
				2	......	18.57	75.04	6.39	.49	......	......	......	......	......	......	......
				3	......	19.84	80.16	......	.52	......	......	......	......	......	......	......
Same (face of B-1 butt entry, off B entry, 6,250 feet northwest of mine mouth, 5-foot 1-inch bed, 4-foot 10-inch cut).	360	14395	A	1	2.77	17.77	74.55	4.91	.52	......	......	......	......	2.0	......	......
				2	......	18.28	76.67	5.05	.53	......	......	......	......	......	......	......
				3	......	19.25	80.75	......	.56	......	......	......	......	......	......	......
Same (face of left boundary heading, 6,200 feet northwest of mine mouth, 5-foot 2-inch bed, 4-foot 10-inch cut).	360	14396	A	1	2.76	17.99	74.20	5.05	.48	......	......	......	......	2.0	......	......
				2	......	18.50	76.81	5.19	.49	......	......	......	......	......	......	......
				3	......	19.51	80.49	......	.52	......	......	......	......	......	......	......
Same (face of room 15, off 3-A entry, off right entry 1, 5,100 feet northeast of mine mouth, 5-foot ½-inch bed, 4-foot 6½-inch cut).	360	14397	A	1	2.65	17.91	76.10	3.34	.50	......	......	......	......	1.9	......	......
				2	......	18.40	78.17	3.43	.51	......	......	......	......	......	......	......
				3	......	19.05	80.95	......	.53	......	......	......	......	......	......	......
Same (face of room 18, off 2-A entry, off right entry 2, 5,000 feet northeast of mine mouth, 5-foot 1½-inch bed, 4-foot 7-inch cut).	360	14398	A	1	3.10	17.56	75.76	3.58	.48	......	......	......	......	2.2	......	......
				2	......	18.12	78.19	3.69	.50	......	......	......	......	......	......	......
				3	......	18.81	81.19	......	.52	......	......	......	......	......	......	......
Same (composite of samples 14394-14398)..........	360	14399	A	1	2.82	17.67	74.95	4.56	.49	4.58	83.92	1.23	5.22	2.0	8,096	14,573
				2	......	18.18	77.13	4.69	.50	4.39	86.35	1.27	2.80	......	8,331	14,996
				3	......	19.07	80.93	......	.52	4.61	90.60	1.33	2.94	......	8,741	15,734
Same (pillar of room 4, off right entry 1, 4,200 feet east of mine mouth, 4-foot 10-inch bed, 4-foot 4-inch cut).	360	14400	A	1	3.03	18.06	76.22	2.69	.55	......	......	......	......	2.3	8,259	14,866
				2	......	18.62	78.61	2.77	.57	......	......	......	......	......	8,517	15,331
				3	......	19.15	80.85	......	.59	......	......	......	......	......	8,760	15,768
Sumas station (Yukon post office), ½ mile west of; Yukon-Pocahontas mine, War Creek bed (face of room 24, off main air course, 1,700 feet southwest of main opening, 4-foot ½-inch bed, 3-foot 8½-inch cut).	361	14426	A	1	1.84	16.89	72.87	8.40	.55	......	......	......	......	.8	......	......
				2	......	17.21	74.23	8.56	.56	......	......	......	......	......	......	......
				3	......	18.82	81.18	......	.61	......	......	......	......	......	......	......
Same (face of main entry, 1,850 feet southwest of main opening, 5-foot 4½-inch bed, 3-foot 8-inch cut).	361	14427	A	1	2.11	17.01	73.39	7.49	.51	......	......	......	......	1.1	......	......
				2	......	17.38	74.97	7.65	.52	......	......	......	......	......	......	......
				3	......	18.82	81.18	......	.56	......	......	......	......	......	......	......

Same (face of room 7, off main air course, 850 feet southwest of main opening, 5-foot 1-inch bed, 4-foot 1-inch cut).	361	14428	A	1	2.53	16.81	72.45	8.21	.63	......	......	......	......	1.5	......	......
				2	......	17.25	74.33	8.42	.65	......	......	......	......	......	......	......
				3	......	18.84	81.16	......	.71	......	......	......	......	......	......	......
Same (face of room 14, off main course, 1,100 feet southwest of main opening, 5-foot 3-inch bed, 3-foot 11½-inch cut).	361	14429	A	1	4.09	16.84	70.08	8.99	.51	......	......	......	......	3.2	......	......
				2	......	17.56	73.07	9.37	.53	......	......	......	......	......	......	......
				3	......	19.38	80.62	......	.58	......	......	......	......	......	......	......
Same (composite of samples 14426-14429)........	361	14430	A	1	2.63	17.19	71.98	8.20	.57	4.44	80.62	1.45	4.72	1.7	7,781	14,006
				2	......	17.65	73.93	8.42	.59	4.26	82.80	1.49	2.44	......	7,991	14,384
				3	......	19.27	80.73	......	.64	4.65	90.41	1.63	2.67	......	8,725	15,705
Same (pillar at last break-through, off third right crosscut, off main entry, 1,200 feet northwest of old opening, 5-foot 9-inch bed, 51½-inch cut).	361	14425	A	1	2.04	16.83	73.05	8.08	.58	......	......	......	......	1.3	7,790	14,022
				2	......	17.18	74.57	8.25	.59	......	......	......	......	......	7,952	14,314
				3	......	18.72	81.28	......	.64	......	......	......	......	......	8,667	15,601
Maybeury; Norfolk mine, Pocahontas No. 3 bed........	361	11247	C	1	2.21	15.78	71.65	10.36	.55	4.08	79.11	1.04	4.86	1.6	7 642	13,756
				2	......	16.14	73.27	10.59	.56	3.92	80.90	1.06	2.97	......	7,815	14,067
				3	......	18.05	81.95	......	.63	4.38	90.48	1.19	3.32	......	8,740	15,732
Same..	361	11780	C	1	2.97	15.87	71.39	9.77	.52	4.33	79.41	.99	4.98	2.5	7,649	13,768
				2	......	16.36	73.57	10.07	.54	4.12	81.84	1.02	2.41	......	7,883	14,189
				3	......	18.19	81.81	......	.60	4.58	91.01	1.13	2.68	......	8,766	15,779
War, 1 mile south of; John's Branch mine, War Creek bed (face of main entry, 800 feet from mine mouth, 3-foot 4-inch bed, 2-foot 9-inch cut).	362	14468	A	1	2.43	16.96	70.87	9.74	.65	......	......	......	......	1.6	......	......
				2	......	17.38	72.64	9.98	.67	......	......	......	......	......	......	......
				3	......	19.31	80.69	......	.74	......	......	......	......	......	......	......
Same (face of heading 3, off right entry, 3-foot 10-inch bed and cut).	362	14469	A	1	2.00	17.22	71.43	9.35	.57	......	......	......	......	1.2	......	......
				2	......	17.57	72.89	9.54	.58	......	......	......	......	......	......	......
				3	......	19.42	80.58	......	.64	......	......	......	......	......	......	......
Same (face of room 4, off first left air course, 4-foot 4-inch bed, 3-foot 8-inch cut).	362	14470	A	1	2.41	16.94	73.18	7.47	.58	......	......	......	......	1.6	......	......
				2	......	17.36	74.99	7.65	.59	......	......	......	......	......	......	......
				3	......	18.80	81.20	......	.64	......	......	......	......	......	......	......
Same (face of first right butt entry, off left entry 2, 4-foot 4-inch bed, 3-foot 7-inch cut).	362	14471	A	1	2.31	17.10	72.01	8.58	.66	......	......	......	......	1.5	......	......
				2	......	17.50	73.72	8.78	.68	......	......	......	......	......	......	......
				3	......	19.19	80.81	......	.75	......	......	......	......	......	......	......
Same (composite of samples 14468-14471)........	362	14472	A	1	2.24	17.29	71.59	8.88	.64	4.34	80.36	1.29	4.49	1.5	7,751	13,952
				2	......	17.69	73.23	9.08	.65	4.18	82.20	1.32	2.57	......	7,928	14,270
				3	......	19.46	80.54	......	.71	4.60	90.41	1.45	2.83	......	8,720	15,696
War Creek mine, War Creek bed (face of fourth left cross entry, off main entry, 3-foot 4-inch bed and cut).	363	14405	A	1	2.74	16.26	73.06	7.94	.69	......	......	......	......	1.9	......	......
				2	......	16.72	75.12	8.16	.71	......	......	......	......	......	......	......
				3	......	18.20	81.80	......	.77	......	......	......	......	......	......	......
Same (face of main entry, 1,200 feet from mine mouth, 3-foot 11-inch bed and cut).	363	14406	A	1	1.86	16.98	72.05	9.11	.76	......	......	......	......	1.1	......	......
				2	......	17.30	73.42	9.28	.77	......	......	......	......	......	......	......
				3	......	19.07	80.93	......	.85	......	......	......	......	......	......	......
Same (face of room 4, off main air course, about 1,000 feet from mine mouth, 3-foot bed and cut).	363	14407	A	1	1.97	17.03	72.74	8.26	.67	......	......	......	......	1.2	......	......
				2	......	17.37	74.20	8.43	.68	......	......	......	......	......	......	......
				3	......	18.97	81.03	......	.74	......	......	......	......	......	......	......
Same (composite of samples 14405, 14406, and 14407).	363	14408	A	1	2.18	16.36	73.02	8.44	.69	4.20	80.70	1.44	4.53	1.4	7,781	14,006
				2	......	16.72	74.65	8.63	.71	4.05	82.50	1.47	2.64	......	7,955	14,319
				3	......	18.30	81.70	......	.78	4.43	90.30	1.61	2.88	......	8,707	15,673

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WEST VIRGINIA—Continued.																
M'DOWELL COUNTY—continued.																
Jed; Havaco (formerly Jed) mine, Pocahontas No. 3 bed (face of first butt left entry; 5-foot 1¼-inch bed, 4-foot 9¼-inch cut).	355	13775	A	1	2.08	16.39	76.60	4.93	.90	4.20	84.87	1.16	3.94	1.5	8,100	14,580
				2	......	16.74	78.23	5.03	.92	4.05	86.67	1.18	2.15	......	8,272	14,890
				3	......	17.63	82.37	......	.97	4.26	91.26	1.24	2.27	......	8,710	15,678
Jenkinjones; Pocahontas No. 6 mine, Pocahontas No. 3 bed (face of main heading, 250 feet west of mine mouth; 9-foot 6-inch bed, 8-foot 11½-inch cut).	356	14185	A	1	3.01	22.04	69.46	5.49	.49	......	......	......	......	2.4	......	......
				2	......	22.72	71.62	5.66	.51	......	......	......	......	......	......	......
				3	......	24.08	75.92	......	.54	......	......	......	......	......	......	......
Same (face of aircourse, 250 feet from mine mouth; 10-foot 2½-inch bed, 9-foot 2½-inch cut).	356	14186	A	1	3.66	21.78	70.64	3.92	.52	......	......	......	......	3.1	......	......
				2	......	22.61	73.32	4.07	.54	......	......	......	......	......	......	......
				3	......	23.57	76.43	......	.56	......	......	......	......	......	......	......
Same, (composite of samples 14185, 14186, and 14187).	356	14188	A	1	3.36	22.50	68.86.	5.28	.52	4.83	82.51	1.22	5.64	2.7	7,983	14,369
				2	......	23.28	71.26	5.46	.54	4.62	85.38	1.26	2.74	......	8,261	14,870
				3	......	24.63	75.37	......	.57	4.89	90.31	1.33	2.90	......	8,738	15,729
½-mile south of; Pocahontas No. 6 B mine, Pocahontas No. 3 bed (face of main heading, 500 feet from mine mouth; 10-foot 6¾-inch bed, 9-foot 5-foot cut).	356	14187	A	1	3.23	22.45	67.83	6.49	.48	......	......	......	......	2.6	......	......
				2	......	23.20	70.09	6.71	.50	......	......	......	......	......	......	......
				3	......	24.87	75.13	......	.54	......	......	......	......	......	......	......
Same (face of first right cross heading, 350 feet from mine mouth, 9-foot 4-inch bed, 8-foot 10-inch cut).	356	14189	A	1	3.27	22.88	69.36	4.49	.44	......	......	......	......	2.7	8,021	14,438
				2	......	23.65	71.71	4.64	.45	......	......	......	......	......	8,292	14,926
				3	......	24.80	75.20	......	.47	......	......	......	......	......	8,696	15,653
½-mile south of; Pocahontas No. 7 A mine, Pocahontas No. 3 bed (face of main heading, 120 feet from mine mouth, 7-foot 10-inch bed, 7-foot 1½-inch cut).	356	14190	A	1	4.09	22.07	69.05	4.79	.47	......	......	......	......	3.1	7,920	14,256
				2	......	23.01	72.00	4.99	.49	......	......	......	......	......	8,257	14,863
				3	......	24.22	75.78	......	.52	......	......	......	......	......	8,690	15,642
Leckie, ½ mile east of; Leckie No. 1 mine, Pocahontas No. 3 bed (face of room 1, off Monkey heading, 1,700 feet west of mine mouth, 8-foot 2½-inch bed, 7-foot 10-inch cut).	357	14271	A	1	3.53	17.95	75.48	3.04	.53	......	......	......	......	2.9	......	......
				2	......	18.61	78.24	3.15	.55	......	......	......	......	......	......	......
				3	......	19.21	80.79	......	.57	......	......	......	......	......	......	......
Same (face of Monkey heading, 1,900 feet west of mine mouth, 8-foot 1½-inch bed, 7-foot 6½-inch cut).	357	14272	A	1	3.39	18.56	74.81	3.24	.52	......	......	......	......	2.7	......	......
				2	......	19.21	77.44	3.35	.54	......	......	......	......	......	......	......
				3	......	19.88	80.12	......	.56	......	......	......	......	......	......	......
Same (face of Kick-back heading, 1,250 feet northwest of mine mouth, 7-foot 10½-inch bed, 7-foot 7½-inch cut).	357	14273	A	1	4.38	18.12	73.92	3.58	.52	......	......	......	......	3.3	......	......
				2	......	18.95	77.31	3.74	.54	......	......	......	......	......	......	......
				3	......	19.69	80.31	......	.56	......	......	......	......	......	......	......

MARION COUNTY.

Monongah, No. 63 (formerly No. 8) mine, Pittsburgh bed (face of room 14, off left entry 3, off north entry 2, 2,700 feet northwest of mouth of main slope, 7-foot ¾-inch bed, 6-foot 9¾-inch cut).	365	11429	A	1	2.65	35.46	56.26	5.63	.70					1.3		
				2		36.42	57.80	5.78	.72							
				3		38.65	61.35		.76							
Same (face of room 14, off left entry 4, off north entry 2, 3,200 feet northwest of mouth of main slope, 7-foot 7¾-inch bed, 7-foot 5-inch cut).	365	11430	A	1	2.67	35.44	55.97	5.92	.73					1.3		
				2		36.41	57.51	6.08	.75							
				3		38.77	61.23		.80							
Same (face of room 18, off left entry 2, off north entry 2, 2,650 feet from mouth of main slope, 7-foot bed, 6-foot 10-inch cut).	365	11431	A	1	3.67	35.28	55.05	6.00	.65					2.4		
				2		36.62	57.15	6.23	.67							
				3		39.05	60.95		.71							
Same (face of room 30, off left entry 1, off north entry 2, 2,900 feet northwest from mouth of main slope, 7-foot 5½-inch bed, 7-foot 3½-inch cut).	365	11432	A	1	2.43	35.76	56.85	4.96	.64					1.1		
				2		36.65	58.27	5.08	.66							
				3		38.61	61.39		.70							
Same (composite of samples 11429–11432)	365	11433	A	1	2.95	35.01	56.44	5.60	.67	5.33	77.89	1.38	9.13	1.5	7,701	13,862
				2		36.07	58.16	5.77	.69	5.15	80.26	1.42	6.71		7,935	14,283
				3		38.28	61.72		.73	5.47	85.17	1.51	7.12		8,421	15,158
Montana Station, ¼ mile northwest of: Parker Run mine Sewickley bed (face of room 8, off right entry 5. 6-foot 2-inch bed, 5-foot 11½-inch cut).	366	15068	A	1	1.77	37.86	50.47	9.90	4.02					.8	7,392	13,306
				2		38.54	51.38	10.08	4.09						7,525	13,545
				3		42.86	57.14		4.55						8,369	15,064
Same (face of room 21. off right entry 3, 6-foot 1-inch bed, 5-foot 11-inch cut).	366	15069	A	1	1.89	37.94	51.51	8.66	3.64					.9	7,504	13,507
				2		38.67	52.50	8.83	3.71						7,649	13,768
				3		42.42	57.58		4.07						8,390	15,102
Same (face of fourth left air course, 1,800 feet northeast of mine mouth, 6-foot 3½-inch bed, 5-foot 11½-inch cut).	366	15071	A	1	1.93	39.60	49.35	9.12	4.17					.9	7,485	13,473
				2		40.38	50.32	9.30	4.25						7,632	13,738
				3		44.52	55.48		4.69						8,414	15,145
Same (composite of samples 15068, 15069, and 15071).	366	15072	A	1	1.81	39.06	49.81	9.32	3.90	5.15	73.62	1.30	6.71	.9	7,453	13,415
				2		39.78	50.73	9.49	3.97	5.04	74.97	1.32	5.21		7,590	13,662
				3		43.95	56.05		4.39	5.57	82.83	1.46	5.75		8,386	15,095
Same (pillar on main entry, at mouth of right entry 7; 2,400 feet northeast of mine mouth; 5-foot 11½-inch bed, 65-inch cut).	366	15067	A	1	1.75	39.22	49.56	9.47	3.68					.8	7,471	13,448
				2		39.92	50.44	9.64	3.75						7.604	13,687
				3		44.18	55.82		4.15						8.415	15,147
Same (pillar on main air course, at mouth of left entry 2, 5-foot 5-inch bed, 62-inch cut).	366	15070	A	1	1.89	38.98	49.11	10.02	4.08					.9	7,372	13,270
				2		39.73	50.06	10.21	4.16						7.514	13,525
				3		44.25	55.75		4.63						8,368	15,062
Worthington; Hutchinson mine, Pittsburgh bed (on pillar 15 on left heading 3, 2,500 feet south of mouth of main slope, 8-foot ½-inch bed and cut).	366	11152	A	1	2.60	35.19	53.48	8.73	1.92					1.4		
				2		36.13	54.91	8.96	1.97							
				3		39.69	60.31		2.16							
Same (on pillar 20 on left heading 1, 1,500 feet south of mouth of main slope, 7-foot 7¼-inch bed and cut).	366	11153	A	1	2.26	36.90	52.03	8.81	2.47					1.3		
				2		37.75	53.24	9.01	2.53							
				3		41.49	58.51		2.78							
Same (face of room 8, off left butt entry 4, 3,000 feet south of mouth of main slope, 8-foot 3⅞-inch bed, 8 foot 3¼-inch cut).	366	11154	A	1	2.67	35.09	54.24	8.00	2.06					1.3		
				2		36.05	55.73	8.22	2.12							
				3		39.28	60.72		2.31							
Same (face of room 10, off left heading 2, 1,000 feet south of mouth of main slope, 7-foot 7¼-inch bed and cut).	366	11155	A	1	2.66	35.99	52.73	8.62	2.04					1.5		
				2		36.97	54.17	8.86	2.10							
				3		40.56	59.44		2.30							
Same (composite of samples 11152–11155)	366	11156	A	1	2.60	35.88	52.83	8.69	2.03	5.22	74.69	1.25	8.12	1.4	7,508	13,513
				2		36.84	54.24	8.92	2.08	5.06	76.68	1.28	5.98		7.708	13,874
				3		40.45	59.55		2.28	5.56	84.19	1.41	6.56		8.463	15.233

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WEST VIRGINIA—Continued.																
MARSHALL COUNTY.																
Moundsville, 1 mile south of: Panama mine, Pittsburgh bed (face of second south air course, 2,050 feet southeast of shaft, 4-foot 9½-inch bed, 4-foot 8½-inch cut).	367	14486	A	1	3.35	41.35	48.29	7.01	3.19	......	......	......	......	1.6	......	......
				2	......	42.78	49.97	7.25	3.30	......	......	......	......	......	......	......
				3	......	46.13	53.87	......	3.56	......	......	......	......	......	......	......
Same (face of room 3, off right entry 2, off north entry 2, 1,700 feet northeast of shaft, 4-foot 7½-inch bed, 4-foot 5½ inch cut).	367	14487	A	1	3.52	41.08	48.34	7.06	3.24	......	......	......	......	1.8	......	......
				2	......	42.58	50.10	7.32	3.36	......	......	......	......	......	......	......
				3	......	45.94	54.06	......	3.63	......	......	......	......	......	......	......
Same (composite of samples 14486 and 14487).....	367	14488	A	1	3.39	41.58	48.01	7.02	3.25	5.38	72.86	1.32	10.17	1.7	7,396	13,313
				2	......	43.04	49.69	7.27	3.36	5.18	75.42	1.37	7.40	......	7,656	13,781
				3	......	46.41	53.59	......	3.62	5.59	81.33	1.48	7.98	......	8,256	14,861
MERCER COUNTY.																
Crystal, ½-mile southeast of: Godfrey mine, Pocahontas No. 3 bed (pillar of right entry 2, 1,100 feet northeast of mine mouth, 4-foot bed, 3-foot 7-inch cut).	368	14258	A	1	2.74	18.41	75.33	3.52	.71	......	......	......	......	2.0	......	......
				2	......	18.93	77.45	3.62	.73	......	......	......	......	......	......	......
				3	......	19.64	80.36	......	.76	......	......	......	......	......	......	......
Same (room 3, off left heading 2, off old main entry, 700 feet southeast of mine mouth, 4-foot 3-inch bed, 4-foot cut).	368	14259	A	1	3.36	17.68	74.76	4.20	.72	......	......	......	......	2.6	......	......
				2	......	18.30	77.35	4.35	.75	......	......	......	......	......	......	......
				3	......	19.13	80.87	......	.78	......	......	......	......	......	......	......
Same (composite of samples 14258 and 14259).....	368	14260	A	1	3.06	18.24	74.84	3.86	.71	4.74	84.32	1.12	5.25	2.3	8,160	14,688
				2	......	18.82	77.20	3.98	.73	4.54	86.98	1.16	2.61	......	8,418	15,152
				3	......	19.60	80.40	......	.76	4.73	90.58	1.21	2.72	......	8,767	15,781
Same (face of room 4, next to "Crystal," 4-foot 7-inch bed, 4-foot 3-inch cut).	368	14261	A	1	3.26	17.99	75.20	3.55	.68	......	......	......	......	2.5	8,163	14,693
				2	......	18.60	77.73	3.67	.70	......	......	......	......	......	8,438	15,188
				3	......	19.31	80.69	......	.73	......	......	......	......	......	8,759	15,766
Goodwill, ½ mile northeast of: Goodwill mine, Pocahontas No. 3 bed (face of room 16, off eighth left cross entry, 3,700 feet northeast of No. 3 drift mouth, 4-foot 9-inch bed, 4-foot 4-inch cut).	369	14163	A	1	3.14	18.91	73.92	4.03	.58	......	......	......	......	2.4	......	......
				2	......	19.52	76.32	4.16	.60	......	......	......	......	......	......	......
				3	......	20.37	79.63	......	.63	......	......	......	......	......	......	......

Same (face of room 3, off second crosscut, off Smith's entry, 3,000 feet northeast of No. 3 drift mouth, 4-foot 9-inch bed, 4-foot 4-inch cut).	369	14164	A	1	3.09	18.22	75.83	2.86	.57	......	......	......	......	2.4	......	......
				2	......	18.80	78.25	2.95	.59	......	......	......	......	......	......	......
				3	......	19.37	80.63	......	.61	......	......	......	......	......	......	......
Same (face of first crosscut, off Nichol's entry, 2,850 feet east of No. 2 drift mouth 4-foot 6-inch bed, 4-foot 1-inch cut).	369	14165	A	1	3.12	18.90	74.76	3.22	.56	......	......	......	......	2.5	......	......
				2	......	19.51	77.17	3.32	.58	......	......	......	......	......	......	......
				3	......	20.18	79.82	......	.60	......	......	......	......	......	......	......
Same (pillar 4, 2,400 feet east of No. 2 drift mouth, 4-foot 5½-inch bed, 4-foot 1-inch cut).	369	14166	A	1	3.49	18.59	74.98	2.94	.54	......	......	......	......	2.9	......	......
				2	......	19.26	77.69	3.05	.56	......	......	......	......	......	......	......
				3	......	19.87	80.13	......	.58	......	......	......	......	......	......	......
Same (composite of samples 14163–14166)......	369	14167	A	1	3.19	19.14	74.36	3.31	.56	4.60	85.16	1.10	5.27	2.6	8,175	14,715
				2	......	19.77	76.81	3.42	.58	4.39	87.97	1.14	2.50	......	8,445	15,201
				3	......	20.47	79.53	......	.60	4.55	91.08	1.18	2.59	......	8,744	15,739
½ mile northwest of; Louisville No. 1 mine (pillar of main entry, 900 feet northeast of mine mouth, 4-foot 10-inch bed, 4-foot 5-inch cut).	370	14207	A	1	3.11	19.30	74.27	3.32	.57	......	......	......	......	2.5	......	......
				2	......	19.92	76.65	3.43	.59	......	......	......	......	......	......	......
				3	......	20.63	79.37	......	.61	......	......	......	......	......	......	......
½ mile northwest of; Louisville No. 2 mine, Pocahontas No. 3 bed (face of main entry, 5,400 feet northeast of mine mouth, 4-foot 8-inch bed, 4-foot 3-inch cut).	370	14191	A	1	2.92	18.75	75.35	2.98	.56	......	......	......	......	2.3	......	......
				2	......	19.31	77.62	3.07	.58	......	......	......	......	......	......	......
				3	......	19.92	80.08	......	.60	......	......	......	......	......	......	......
Same (face of room 19, off left heading 9, 5,700 feet northeast of mine mouth, 4-foot 6¼-inch bed, 4-foot 2¼-inch cut).	370	14192	A	1	3.54	18.47	74.96	3.03	.48	......	......	......	......	2.8	......	......
				2	......	19.15	77.71	3.14	.50	......	......	......	......	......	......	......
				3	......	19.77	80.23	......	.52	......	......	......	......	......	......	......
Same (rib of room 14, off left heading 6, 4,500 feet northeast of mine mouth, 4-foot 6½-inch bed, 4-foot 2½-inch cut).	370	14193	A	1	3.12	18.64	74.37	3.87	.50	......	......	......	......	2.4	......	......
				2	......	19.24	76.77	3.99	.52	......	......	......	......	......	......	......
				3	......	20.04	79.96	......	.54	......	......	......	......	......	......	......
Same (rib of room 13, off left heading 4, 3,000 feet northeast of mine mouth, 4-foot 8-inch bed, 4-foot 5½-inch cut).	370	14194	A	1	2.61	18.85	73.59	4.95	.49	......	......	......	......	1.9	......	......
				2	......	19.36	75.56	5.08	.50	......	......	......	......	......	......	......
				3	......	20.40	79.60	......	.53	......	......	......	......	......	......	......
1 mile northwest of; Louisville No. 3 mine (barrier pillar between second left air course and second left pillar, 1,500 feet northwest of mine mouth, 5-foot 1-inch bed, 4-foot 9-inch cut).	370	14195	A	1	3.10	19.11	73.73	4.06	.47	......	......	......	......	2.5	......	......
				2	......	19.72	76.09	4.19	.49	......	......	......	......	......	......	......
				3	......	20.58	79.42	......	.51	......	......	......	......	......	......	......
Same (face, 1,950 feet northeast of mine mouth, 4-foot 9-inch bed, 4-foot 5-inch cut).	370	14206	A	1	4.10	19.18	73.60	3.12	.53	......	......	......	......	3.5	......	......
				2	......	20.00	76.75	3.25	.55	......	......	......	......	......	......	......
				3	......	20.67	79.33	......	.57	......	......	......	......	......	......	......
Same (composite of samples 14191, 14192, 14193, 14194, 14195, 14206, and 14207).	370	14196	A	1	3.30	18.58	74.45	3.67	.56	4.56	84.83	1.16	5.22	2.6	8,142	14,656
				2	......	19.21	76.99	3.80	.58	4.33	87.72	1.20	2.37	......	8,420	15,156
				3	......	19.97	80.03	......	.60	4.50	91.18	1.25	2.47	......	8,753	15,755
Matoaka; Pawama No. 1 mine (pillar of room 14, off Walker heading, 1,000 feet north of mine mouth, 4-foot 7½-inch bed, 4-foot ½-inch cut).	371	14235	A	1	3.55	17.17	75.19	4.09	.76	......	......	......	......	2.8	......	......
				2	......	17.80	77.96	4.24	.79	......	......	......	......	......	......	......
				3	......	18.59	81.41	......	.82	......	......	......	......	......	......	......
Same (pillar on Godfrey heading, 1,520 feet southwest of mine mouth, 4-foot 5-inch bed, 3-foot 11½-inch cut).	371	14236	A	1	2.58	17.56	76.50	3.36	.73	......	......	......	......	1.9	......	......
				2	......	18.03	78.52	3.45	.75	......	......	......	......	......	......	......
				3	......	18.67	81.33	......	.78	......	......	......	......	......	......	......
Same (composite of samples 14235 and 14236)......	371	14237	A	1	3.16	16.98	76.21	3.65	.71	4.64	84.79	1.15	5.06	2.4	8,183	14,729
				2	......	17.53	78.70	3.77	.73	4.43	87.55	1.19	2.33	.....	8,450	15,210
				3	......	18.22	81.78	......	.76	4.60	90.98	1.24	2.42	......	8,781	15,806

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WEST VIRGINIA—Continued.																
MERCER COUNTY—continued.																
Matoaka; Pawama No. 2 mine, Pocahontas No. 3 bed (face of Roanoke heading, 2,060 feet southwest of mine mouth, 4-foot 4¾-inch bed, 4-foot 2-inch cut).	371	14231	A	1	4.35	17.33	74.16	4.16	.75	......	......	......	......	3.7	......	......
				2	......	18.12	77.53	4.35	.78	......	......	......	......	......	......	......
				3	......	18.94	81.06	......	.82	......	......	......	......	......	......	......
Same (face of main entry, 2,600 feet southwest of mine mouth, 4-foot 3¾-inch bed, 4-foot 1-inch cut).	371	14232	A	1	3.28	17.14	75.57	4.01	.77	......	......	......	......	2.6	......	......
				2	......	17.72	78.13	4.15	.80	......	......	......	......	......	......	......
				3	......	18.49	81.51	......	.83	......	......	......	......	......	......	......
Same (face of room 20, off Norfolk entry, 2,300 feet southwest of mine mouth, 4-foot 5½-inch bed, 4-foot cut).	371	14233	A	1	3.02	17.59	75.00	4.39	.78	......	......	......	......	2.3	......	......
				2	......	18.14	77.33	4.53	.80	......	......	......	......	......	......	......
				3	......	19.00	81.00	......	.84	......	......	......	......	......	......	......
Same (composite of samples 14231, 14232, and 14233).	371	14234	A	1	3.61	17.41	74.84	4.14	.76	4.57	83.68	1.12	5.73	2.9	8,104	14,587
				2	......	18.06	77.64	4.30	.79	4.33	86.82	1.16	2.60	......	8,408	15,134
				3	......	18.87	81.13	......	.83	4.52	90.72	1.21	2.72	......	8,786	15,815
Mora, ½ mile west of; Crane Creek No. 1 mine, Pocahontas No. 3 bed (face of main heading, 4-foot 11-inch bed, 4-foot 6½-inch cut).	372	W32517	A	1	2.3	18.0	73.3	6.4	.60	......	......	......	......	......	7,978	14,360
				2	......	18.4	75.1	6.5	.60	......	......	......	......	......	8,167	14,700
				3	......	19.7	80.3	......	.64	......	......	......	......	......	8,733	15,720
Same (face of eighteenth cross air course, 4-foot 9-inch bed, 4-foot 4½-inch cut).	372	W32518	A	1	2.3	17.9	74.3	5.5	.55	......	......	......	......	......	8,072	14,530
				2	......	18.3	76.1	5.6	.55	......	......	......	......	......	8,267	14,880
				3	......	19.4	80.6	......	.58	......	......	......	......	......	8,756	15,760
Same (pillar beyond second break-through in room 11, off cross entry 16, 5-foot 7¾-inch bed, 5-foot 3-inch cut).	372	W32519	A	1	2.2	17.0	75.1	5.7	.70	......	......	......	......	......	8,083	14,550
				2	......	17.4	76.8	5.8	.70	......	......	......	......	......	8,267	14,880
				3	......	18.5	81.5	......	.74	......	......	......	......	......	8,778	15,800
Same (pillar beyond second break-through in room 21, off cross entry 6, 4-foot 5-inch bed, 4-foot 3½-inch cut).	372	W32520	A	1	2.4	17.6	74.9	5.1	.65	......	......	......	......	......	8,128	14,630
				2	......	18.0	76.8	5.2	.65	......	......	......	......	......	8,322	14,980
				3	......	19.0	81.0	......	.69	......	......	......	......	......	8,778	15,800
½ mile west of; Crane Creek No. 2 mine, Pocahontas No. 3 bed (cut from pocket beyond second break-through in room 4, off cross entry 3, 5-foot ½-inch bed, 4-foot 4½-inch cut).	372	W32600	A	1	3.3	17.5	73.7	5.5	.55	......	......	......	......	......	7,967	14,340
				2	......	18.1	76.2	5.7	.55	......	......	......	......	......	8,244	14,840
				3	......	19.2	80.8	......	.58	......	......	......	......	......	8,744	15,740
Same (face of room 14, off Allegheny entry, 5-foot 3-inch bed, 4-foot 10-inch cut).	372	W32601	A	1	2.0	18.5	75.5	4.0	.60	......	......	......	......	......	8,256	14,860
				2	......	18.9	77.0	4.1	.60	......	......	......	......	......	8,422	15,160
				3	......	19.7	80.3	......	.63	......	......	......	......	......	8,783	15,810

Same (chain pillar between rooms 21 and 22, off Blue Ridge entry, 5-foot ¾-inch bed, 4-foot 9-inch cut).	372	W32602	A	1	2.1	18.8	74.9	4.2	.55	......	......	......	......	......	8,200	14,760
				2	......	19.2	76.5	4.3	.55	......	......	......	......	......	8,378	15,080
				3	......	20.1	79.9	......	.57	......	......	......	......	......	8,756	15,760
Same (face of room 13, off Bryant entry, 4-foot 8½-inch bed, 4-foot 1-inch cut).	372	W32603	A	1	2.4	18.3	75.4	3.9	.55	......	......	......	......	......	8,211	14,780
				2	......	18.8	77.2	4.0	.55	......	......	......	......	......	8,411	15,140
				3	......	19.6	80.4	......	.57	......	......	......	......	......	8,761	15,770
1 mile north of; Pinnacle mine, Pocahontas No. 3 bed (face of cross entry 2, north mine, 4-foot 2¾-inch bed, 3-foot 11¾-inch cut).	373	W32604	A	1	2.4	18.1	76.3	3.2	.55	......	......	......	......	......	8,261	14,870
				2	......	18.6	78.1	3.3	.55	......	......	......	......	......	8,467	15,240
				3	......	19.2	80.8	......	.57	......	......	......	......	......	8,756	15,760
Same (face of north main heading, 4-foot 4½-inch bed, 4-foot cut).	373	W32605	A	1	2.7	17.3	76.4	3.6	.55	......	......	......	......	......	8,217	14,790
				2	......	17.8	78.5	3.7	.55	......	......	......	......	......	8,444	15,200
				3	......	18.5	81.5	......	.57	......	......	......	......	......	8,767	15,780
Same (face of pocket in first pillar of room 25, cross entry 2, off main heading, 4-foot 8½-inch bed, 4-foot 3-inch cut).	373	W32606	A	1	2.4	17.8	75.7	4.1	.60	......	......	......	......	......	8,183	14,730
				2	......	18.2	77.6	4.2	.60	......	......	......	......	......	8,383	15,090
				3	......	19.0	81.0	......	.63	......	......	......	......	......	8,750	15,750
Same (face of break-through off Cuba entry, off main heading 2, 4-foot 9¾-inch bed, 4-foot 4-inch cut).	373	W32607	A	1	2.4	18.3	75.5	3.8	.55	......	......	......	......	......	8,200	14,760
				2	......	18.7	77.4	3.9	.55	......	......	......	......	......	8,400	15,120
				3	......	19.5	80.5	......	.57	......	......	......	......	......	8,744	15,740
Same (face of main heading 2, 4-foot 8¼-inch bed, 4-foot 4-inch cut).	373	W32608	A	1	2.6	17.8	75.9	3.7	.60	......	......	......	......	......	8,211	14,780
				2	......	18.3	77.9	3.8	.60	......	......	......	......	......	8,433	15,180
				3	......	19.0	81.0	......	.62	......	......	......	......	......	8,767	15,780
Same (pillar of room 16, off cross entry 4, off main heading 1, 4-foot 11-inch bed, 4-foot 6-inch cut).	373	W32609	A	1	2.8	17.1	76.3	3.8	.55	......	......	......	......	......	8,172	14,710
				2	......	17.6	78.5	3.9	.55	......	......	......	......	......	8,406	15,130
				3	......	18.3	81.7	......	.57	......	......	......	......	......	8,744	15,740
1 mile west of; Sagamore No. 1 mine, Pocahontas No. 3 bed (face of main straight entry H, 2,250 feet northwest of mine mouth, 5-foot bed, 3-foot 11-inch cut).	374	14250	A	1	2.53	18.56	74.89	4.02	.52	......	......	......	......	1.8	......	......
				2	......	19.04	76.84	4.12	.53	......	......	......	......	......	......	......
				3	......	19.86	80.14	......	.55	......	......	......	......	......	......	......
Same (face of G–1 heading, 2,250 feet west of mine mouth, 5-foot 6½-inch bed, 4-foot 9-inch cut).	374	14251	A	1	3.20	18.43	74.24	4.13	.57	......	......	......	......	2.4	......	......
				2	......	19.04	76.69	4.27	.59	......	......	......	......	......	......	......
				3	......	19.89	80.11	......	.62	......	......	......	......	......	......	......
Same (face of room 11, off G–2 heading, 1,900 feet southwest of mine mouth, 5-foot 11-inch bed, 4-foot 11-inch cut).	374	14252	A	1	3.53	18.20	74.99	3.28	.54	......	......	......	......	2.7	......	......
				2	......	18.87	77.73	3.40	.56	......	......	......	......	......	......	......
				3	......	19.53	80.47	......	.58	......	......	......	......	......	......	......
1 mile east of; Sagamore No. 2 mine (face of H–8 entry, 2,550 feet southeast of mine mouth, 4-foot 6-inch bed, 4-foot 2-inch cut).	375	14253	A	1	3.36	18.33	74.93	3.38	.57	......	......	......	......	2.6	......	......
				2	......	18.97	77.53	3.50	.59	......	......	......	......	......	......	......
				3	......	19.66	80.34	......	.61	......	......	......	......	......	......	......
Same (face of G–6 entry, 2,300 feet southwest of mine mouth, 4-foot 5½-inch bed, 4-foot 1½-inch cut).	375	14254	A	1	2.62	18.56	74.98	3.84	.55	......	......	......	......	1.8	......	......
				2	......	19.06	77.00	3.94	.56	......	......	......	......	......	......	......
				3	......	19.84	80.16	......	.58	......	......	......	......	......	......	......
Same (face of G–8 entry, 2,550 feet south of mine mouth, 4-foot 6-inch bed, 4-foot 2-inch cut).	375	14255	A	1	3.24	18.24	75.19	3.33	.61	......	......	......	......	2.4	......	......
				2	......	18.85	77.71	3.44	.63	......	......	......	......	......	......	......
				3	......	19.52	80.48	......	.65	......	......	......	......	......	......	......
Same (face of straight H air course, 2,350 feet southeast of mine mouth, 4-foot 6-inch bed and cut).	375	14256	A	1	3.11	18.18	73.38	5.33	.56	......	......	......	......	2.3	......	......
				2	......	18.76	75.74	5.50	.58	......	......	......	......	......	......	......
				3	......	19.85	80.15	......	.61	......	......	......	......	......	......	......
Same (composite of samples 14250–14256)........	375	14257	A	1	3.16	18.17	74.69	3.98	.56	4.60	84.13	1.17	5.56	2.3	8,133	14,639
				2	......	18.76	77.13	4.11	.58	4.39	86.87	1.21	2.84	......	8,398	15,116
				3	......	19.56	80.44	......	.60	4.58	90.60	1.26	2.96	......	8,758	15,764

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WEST VIRGINIA—Continued.																
MERCER COUNTY—continued.																
Weyanoke: Weyanoke No. 1 mine; Pocahontas No. 3 bed (face of room 11, off left entry 9, off main heading, 4-foot 1½-inch bed, 3-foot 11-inch cut).	376	14224	A	1	2.57	18.66	75.35	3.42	.56	......	......	......	......	3.0	......	......
				2	......	19.15	77.34	3.51	.57	......	......	......	......	......	......	......
				3	......	19.85	80.15	......	.59	......	......	......	......	......	......	......
Same (face of main air course; 4-foot ½-inch bed, 3-foot 10-inch cut).	376	14225	A	1	2.74	18.81	74.42	4.03	.60	......	......	......	......	2.1	......	......
				2	......	19.34	76.52	4.14	.62	......	......	......	......	......	......	......
				3	......	20.18	79.82	......	.65	......	......	......	......	......	......	......
Same (face of room 22, off left cross heading 8, 4-foot 6-inch bed, 4-foot 3-inch cut).	376	14226	A	1	3.25	17.33	75.40	4.02	.63	......	......	......	......	2.6	......	......
				2	......	17.91	77.93	4.16	.65	......	......	......	......	......	......	......
				3	......	18.69	81.31	......	.68	......	......	......	......	......	......	......
Same (face of room 6, off left entry 6, 4-foot 3½-inch bed, 4-foot cut).	376	14228	A	1	3.22	17.84	75.47	3.47	.59	......	......	......	......	2.5	......	......
				2	......	18.43	77.98	3.59	.61	......	......	......	......	......	......	......
				3	......	19.12	80.88	......	.63	......	......	......	......	......	......	......
Weyanoke No. 2 mine, Pocahontas No. 3 bed (face of right entry 3, off main entry, 4-foot bed, 3-foot 11-inch cut).	376	14227	A	1	3.10	18.06	75.63	3.21	.64	......	......	......	......	2.5	......	......
				2	......	18.64	78.05	3.31	.66	......	......	......	......	......	......	......
				3	......	19.28	80.72	......	.68	......	......	......	......	......	......	......
Same (pillar of last crosscut in room 7, off left butt entry 2; 4-foot 4-inch bed, 3-foot 11-inch cut).	376	14230	A	1	2.74	17.84	75.48	3.94	.63	......	......	......	......	2.0	8,186	14.735
				2	......	18.34	77.61	4.05	.65	......	......	......	......	......	8,417	15,151
				3	......	19.11	80.89	......	.68	......	......	......	......	......	8,772	15,790
Same (composite of samples 14224, 14225, 14226, 14227, and 14228).	376	14229	A	1	2.97	17.72	75.68	3.63	.65	4.52	85.26	1.16	4.78	2.3	8,167	14,701
				2	......	18.26	78.00	3.74	.67	4.32	87.87	1.20	2.20	......	8,417	15,151
				3	......	18.97	81.03	......	.70	4.49	91.29	1.25	2.27	......	8,744	15,739
MONONGALIA COUNTY.																
Richard, ½ mile northeast of; Elkins No. 1 mine, Upper Freeport bed (face of fifth right "flat," 4,200 feet northeast of mine mouth, 4-foot ¾-inch bed, 3-foot 10½-inch cut).	377	W19475	A	1	2.2	28.7	62.1	7.0	.80	......	......	......	......	......	7,828	14,090
				2	......	29.4	63.4	7.2	.80	......	......	......	......	......	8,006	14,410
				3	......	31.7	68.3	......	.86	......	......	......	......	......	8,628	15,530
Same (face of butt entry 8 off right entry 5, 700 feet from main entry, 3-foot 7½-inch bed, 3-foot 6-inch cut).	377	W19476	A	1	2.6	27.2	61.9	8.3	.90	......	......	......	......	......	7,622	13,720
				2	......	27.9	63.6	8.5	.95	......	......	......	......	......	7,828	14,090
				3	......	30.5	69.5	......	1.04	......	......	......	......	......	8,556	15,400

Same (face of right heading 1, 4,200 feet from mine mouth, 4-foot 2¼-inch bed, 4-foot 1⅜-inch cut).	377	W19477	A	1	2.7	27.9	61.1	8.3	.90	......	......	......	......	......	7,672	13,810
				2	......	28.7	62.8	8.5	.95	......	......	......	......	......	7,883	14,190
				3	......	31.4	68.6	......	1.04	......	......	......	......	......	8,611	15,500
Same (face of butt entry 11, off right entry 1, 750 feet from right entry 1, 3-foot 11¼-inch bed, 3-foot 9-inch cut).	377	W19478	A	1	2.2	28.8	61.5	7.5	.90	......	......	......	......	......	7,778	14,000
				2	......	29.1	63.2	7.7	.95	......	......	......	......	......	7,950	14,310
				3	......	31.5	68.5	......	1.03	......	......	......	......	......	8,617	15,510
Same (butt entry 5, off fifth right "flat," 1,400 feet from fifth "flat," 4-foot ½-inch bed, 3-foot 10½-inch cut).	377	W19479	A	1	2.7	28.2	60.3	8.8	.70	......	......	......	......	......	7,617	13,710
				2	......	29.0	62.0	9.0	.75	......	......	......	......	......	7,822	14,080
				3	......	31.9	68.1	......	.82	......	......	......	......	......	8,594	15,470
Same (composite of samples 19475-19479).........	377	12204	A	1	1.63	28.42	62.01	7.94	.96	5.00	78.24	1.28	6.58	......	7,743	13,937
				2	......	28.89	63.04	8.07	.98	4.90	79.54	1.30	5.21	......	7,872	14,170
				3	......	31.43	68.57	......	1.07	5.33	86.52	1.41	5.67	......	8,563	15,313
PRESTON COUNTY.																
Masontown, at; Elkins No. 6 mine, Upper Freeport bed (face of butt heading 1, 600 feet from third "flat," 150 feet from main entry, 4-foot ⅞-inch bed, 3-feet 11⅜-inch cut).	378	W19493	A	1	2.2	26.5	60.9	10.4	1.85	......	......	......	......	......	7,522	13,540
				2	......	27.1	62.3	10.6	1.90	......	......	......	......	......	7,689	13,840
				3	......	30.3	69.7	......	2.13	......	......	......	......	......	8,606	15,490
Same (face of right entry 3, off main entry, 50 feet from main entry, 4-foot 1⅜-inch bed, 3-foot 11⅛-inch cut).	378	W19494	A	1	2.7	24.2	64.7	8.4	1.15	......	......	......	......	......	7,606	13,690
				2	......	24.9	66.5	8.6	1.20	......	......	......	......	......	7,811	14,060
				3	......	27.2	72.8	......	1.31	......	......	......	......	......	8,544	15,380
Same (face of butt heading 2, 1,000 feet from main entry, 4-foot 1⅜-inch bed, 3-foot 11⅜-inch cut).	378	W19540	A	1	2.0	27.0	63.1	7.9	.75	......	......	......	......	......	7,739	13,930
				2	......	27.6	64.3	8.1	.75	......	......	......	......	......	7,894	14,210
				3	......	30.0	70.0	......	.82	......	......	......	......	......	8,594	15,470
Same (butt entry 2, 700 feet from second "flat," 300 feet from main entry, 4-foot 3⅜-inch bed, 4-foot ⅜-inch cut).	378	W19541	A	1	2.5	27.0	60.8	9.7	1.70	......	......	......	......	......	7,550	13,590
				2	......	27.7	62.4	9.9	1.75	......	......	......	......	......	7,739	13,930
				3	......	30.7	69.3	......	1.94	......	......	......	......	......	8,589	15,460
Same (composite of samples W19493, W19494, W19540, and W19541).	378	12225	A	1	1.40	26.40	62.92	9.28	1.50	4.83	77.92	1.43	5.04	......	7,671	13,808
				2	......	26.77	63.82	9.41	1.52	4.74	79.03	1.45	3.85	......	7,780	14,004
				3	......	29.55	70.45	......	1.68	5.23	87.24	1.60	4.25	......	8,588	15,458
RALEIGH COUNTY.																
Hotcoal; Big Stick mine, Beckley bed (face of left heading 2, 1,600 feet east of mouth of straight main entry, 5-foot 6-inch bed, 5-foot 3¼-inch cut).	379	14375	A	1	2.82	16.64	75.57	4.97	.52	......	......	......	......	2.0	......	......
				2	......	17.12	77.77	5.11	.54	......	......	......	......	......	......	......
				3	......	18.04	81.96	......	.57	......	......	......	......	......	......	......
Same (face of left entry 3, off straight main entry, 1,400 feet northeast of mine mouth, 5-foot 3¼-inch bed and cut).	379	14376	A	1	2.37	17.14	74.95	5.54	.80	......	......	......	......	1.6	......	......
				2	......	17.56	76.77	5.67	.82	......	......	......	......	......	......	......
				3	......	18.62	81.38	......	.87	......	......	......	......	......	......	......
Same (face of straight main entry, 1,900 feet northeast of mine mouth, 6-foot 3½-inch bed, 6-foot 1-inch cut).	379	14377	A	1	1.57	17.38	77.05	4.00	.51	......	......	......	......	.7	......	......
				2	......	17.66	78.28	4.06	.52	......	......	......	......	......	......	......
				3	......	18.41	81.59	......	.54	......	......	......	......	......	......	......
Same (composite of samples 14375, 14376, and 14377).	379	14378	A	1	2.24	17.54	75.40	4.82	.63	4.52	83.73	1.62	4.68	1.4	8,096	14,573
				2	......	17.94	77.13	4.93	.64	4.37	85.65	1.66	2.75	......	8,281	14,906
				3	......	18.87	81.13	......	.67	4.60	90.09	1.75	2.89	......	8,710	15,678

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WEST VIRGINIA—Continued.																
RALEIGH COUNTY—continued.																
McQuade station, 2 miles southeast of Raleigh; Blue Jay No. 4 mine, Beckley bed (pillar of main heading, 600 feet east of mine mouth, 4-foot 11-inch bed, 4-foot 2-inch cut).	379	14288	A	1	3.53	19.01	74.38	3.08	.75	......	......	......	......	2.4	......	......
				2	......	19.71	77.10	3.19	.78	......	......	......	......	......	......	......
				3	......	20.36	79.64	......	.81	......	......	......	......	......	......	......
Same (face of right heading 2; 400 feet south of mine mouth; 4-foot 5-inch bed, 4-foot 2-inch cut).	379	14289	A	1	2.89	19.49	73.29	4.33	.78	......	......	......	......	1.8	......	......
				2	......	20.07	75.47	4.46	.80	......	......	......	......	......	......	......
				3	......	21.01	78.99	......	.84	......	......	......	......	......	......	......
Same (pillar of right heading 1; 250 feet south of mine mouth; 4-foot 5-inch bed and cut).	379	14290	A	1	3.40	18.74	72.56	5.30	.66	......	......	......	......	2.3	......	......
				2	......	19.40	75.11	5.49	.68	......	......	......	......	......	......	......
				3	......	20.53	79.47	......	.72	......	......	......	......	......	......	......
Same (composite of samples 14288, 14289, and 14290).	380	14291	A	1	3.29	18.96	73.46	4.29	.74	4.78	82.96	1.61	5.62	2.2	8,066	14,519
				2	......	19.60	75.96	4.44	.77	4.56	85.78	1.66	2.79	......	8,340	15,012
				3	......	20.51	79.49	......	.81	4.77	89.77	1.74	2.91	......	8,728	15,710
Raleigh; No. 1 mine, Beckley bed (neck of the last break-through off right entry 6, 5-foot 1¾-inch bed and cut).	380	10630	A	1	2.80	17.99	75.61	3.60	.63	5.05	83.72	1.56	5.44	2.3	8,170	14,706
				2	......	18.51	77.79	3.70	.65	4.88	86.13	1.60	3.04	......	8,405	15,129
				3	......	19.22	80.78	......	.67	5.07	89.44	1.66	3.16	......	8,728	15,710
No. 3 mine, Beckley bed (left rib of left entry 7, opposite mouth of right heading 1, 5-foot 2½-inch bed and cut).	380	10624	A	1	3.47	18.07	74.87	3.59	.66	......	......	......	......	2.9	......	......
				2	......	18.72	77.56	3.72	.68	......	......	......	......	......	......	......
				3	......	19.44	80.56	......	.71	......	......	......	......	......	......	......
Same (face of right entry 15, 4-foot 2-inch bed and cut).	380	10625	A	1	1.58	18.87	76.37	3.18	.68	......	......	......	......	1.1	......	......
				2	......	19.17	77.60	3.23	.69	......	......	......	......	......	......	......
				3	......	19.81	80.19	......	.71	......	......	......	......	......	......	......
Same (last crosscut in main entry, 4-foot 1¾-inch bed and cut).	380	10626	A	1	8.77	17.22	70.26	3.75	.73	......	......	......	......	8.2	......	......
				2	......	18.87	77.02	4.11	.80	......	......	......	......	......	......	......
				3	......	19.68	80.32	......	.83	......	......	......	......	......	......	......
Same (face of room 11, off right heading 12, 3-foot 7½-inch bed and cut).	380	10627	A	1	2.76	19.89	73.82	3.53	.81	......	......	......	......	2.3	......	......
				2	......	20.45	75.92	3.63	.83	......	......	......	......	......	......	......
				3	......	21.22	78.78	......	.86	......	......	......	......	......	......	......
Same (composite of samples 10624-10627)........	380	10628	A	1	4.37	18.06	74.08	3.49	.71	4.95	82.72	1.49	6.64	3.8	8,039	14,470
				2	......	18.89	77.46	3.65	.74	4.66	86.50	1.56	2.89	......	8,406	15,131
				3	......	19.61	80.39	......	.77	4.84	89.78	1.62	2.99	......	8,724	15,703

Slab Fork, about ¾ mile northeast of; Slab Fork No. 1 mine, Beckley bed (pillar of room 7 off right entry 2; 1,200 feet northeast of mine mouth 5-foot 4½-inch bed, 4-foot 10½-inch cut).	381	14337	A	1	4.93	19.96	72.38	2.73	.58	4.77	81.61	1.58	8.73	2.8	7,872	14,170
				2	....	21.00	76.13	2.87	.61	4.44	85.85	1.66	4.57	....	8,281	14,906
				3	....	21.62	78.38	....	.63	4.57	88.38	1.71	4.71	....	8,525	15,345
About ¾ mile northeast of; Slab Fork No. 2 mine, Beckley bed (pillar of left entry 3, between rooms 7 and 8, 1,800 feet southwest of mine mouth, 5-foot 6½-inch bed, 4-foot 10-inch cut).	381	14325	A	1	2.07	17.83	75.30	4.80	.53	....	....	....	....	1.3	....	....
				2	....	18.21	76.89	4.90	.54	....	....	....	....	....	....	....
				3	....	19.15	80.85	....	.57	....	....	....	....	....	....	....
Same (pillar between rooms 8 and 10, off left entry 7; 3,000 feet southwest of mine mouth, 4-foot 6-inch bed, 4-foot cut).	381	14326	A	1	2.38	17.52	77.33	2.77	.52	....	....	....	....	1.5	....	....
				2	....	17.95	79.21	2.84	.53	....	....	....	....	....	....	....
				3	....	18.47	81.53	....	.55	....	....	....	....	....	....	....
Same (composite of samples 14325 and 14326).....	381	14327	A	1	2.27	17.26	76.73	3.74	.54	4.62	84.90	1.57	4.63	1.4	8,196	14,753
				2	....	17.66	78.51	3.83	.55	4.47	86.87	1.61	2.67	....	8,386	15,095
				3	....	18.36	81.64	....	.57	4.65	90.33	1.67	2.78	....	8,720	15,696
Same (face of first panel off second drift, 4,200 feet south of mine mouth, 4-foot 2-inch bed, 3-foot 8-inch cut).	381	14328	A	1	2.57	17.60	77.16	2.67	.50	....	....	....	....	1.6	....	....
				2	....	18.06	79.20	2.74	.51	....	....	....	....	....	....	....
				3	....	18.57	81.43	....	.52	....	....	....	....	....	....	....
Same (face of right entry 1, off left entry 3; 1,200 feet southeast of mine mouth, 4-foot 4¾-inch bed, 4-foot ¾-inch cut).	381	14329	A	1	2.09	17.83	75.93	4.15	.53	....	....	....	....	1.3	....	....
				2	....	18.21	77.55	4.24	.54	....	....	....	....	....	....	....
				3	....	19.02	80.98	....	.56	....	....	....	....	....	....	....
Same (face of left entry 14, 150 feet from straight main entry, 5,000 feet southwest of mine mouth, 4-foot 6-inch bed, 4-foot cut).	381	14330	A	1	2.58	17.88	76.41	3.13	.48	....	....	....	....	1.8	....	....
				2	....	18.35	78.44	3.21	.49	....	....	....	....	....	....	....
				3	....	18.96	81.04	....	.51	....	....	....	....	....	....	....
Same (composite of samples 14328, 14329, and 14330).	382	14331	A	1	2.45	17.52	76.67	3.36	.48	4.56	85.51	1.51	4.58	1.6	8,216	14,789
				2	....	17.96	78.60	3.44	.49	4.40	87.66	1.55	2.46	....	8,422	15,160
				3	....	18.60	81.40	....	.51	4.56	90.78	1.61	2.54	....	8,722	15,700
About ¾ mile northeast of; Slab Fork No. 3 mine, Beckley bed (face of main air course, 2,450 feet southeast of mine mouth, 5-foot 3½-inch bed, 4-foot 10½-inch cut).	382	14332	A	1	2.44	18.00	76.15	3.41	.60	....	....	....	....	1.6	....	....
				2	....	18.45	78.05	3.50	.62	....	....	....	....	....	....	....
				3	....	19.12	80.88	....	.64	....	....	....	....	....	....	....
Same (face of A entry, 2,350 feet southeast of mine mouth, 4-foot 2-inch bed, 3-foot 8½-inch cut).	382	14333	A	1	3.38	17.70	75.94	2.98	.48	....	....	....	....	2.4	....	....
				2	....	18.32	78.60	3.08	.50	....	....	....	....	....	....	....
				3	....	18.90	81.10	....	.52	....	....	....	....	....	....	....
Same (face of room 3, off right entry 1; 2,600 feet southeast of mine mouth, 4-foot 5-inch bed, 4-foot 1-inch cut).	382	14334	A	1	2.34	17.40	75.86	4.40	.53	....	....	....	....	1.4	....	....
				2	....	17.82	77.67	4.51	.54	....	....	....	....	....	....	....
				3	....	18.66	81.34	....	.57	....	....	....	....	....	....	....
Same (composite of samples 14332, 14333, and 14334).	382	14335	A	1	2.71	17.57	76.15	3.57	.56	4.56	84.52	1.51	5.28	1.8	8,176	14,717
				2	....	18.06	78.27	3.67	.58	4.38	86.88	1.55	2.94	....	8,404	15,127
				3	....	18.75	81.25	....	.60	4.55	90.19	1.61	3.05	....	8,724	15,703
About ¾ mile northeast of; Slab Fork No. 4 mine, Beckley bed (face of main entry, 1,450 feet northwest of mine mouth; 4-foot ½-inch bed, 3-foot 9½-inch cut).	381	14336	A	1	2.22	18.21	77.23	2.34	.54	4.54	86.47	1.51	4.60	1.3	8,343	15,017
				2	....	18.62	78.99	2.39	.55	4.39	88.43	1.54	2.70	......	8,532	15,358
				3	....	19.08	80.92	....	.56	4.50	90.60	1.58	2.76	....	8,741	15,734
¼ mile south of; Slab Fork No. 5 mine, Beckley bed (face of line heading (main), 3,200 feet southwest of mine mouth, 4-foot 5-inch bed, 3-foot 10-inch cut).	382	14313	A	1	3.50	17.71	75.35	3.44	.47	....	....	....	....	3.0	....	....
				2	....	18.35	78.09	3.56	.49	....	....	....	....	....	....	....
				3	....	19.03	80.97	....	.51	....	....	....	....	....	....	....
Same (face of room 15, off left entry 6; 2,000 feet southwest of mine mouth, 3-foot 7-inch bed, 3-foot 6½-inch cut).	392	14314	A	1	3.10	17.88	76.41	2.61	.48	....	....	....	....	2.5	....	....
				2	....	18.45	78.86	2.69	.50	....	....	....	....	....	....	....
				3	....	18.96	81.04	....	.51	....	....	....	....	....	....	....
Same (last cut-through off left entry 3; 1,900 feet southeast of mine mouth, 3-foot 7½-inch bed and cut).	382	14315	A	1	3.41	17.45	74.64	4.50	.46	....	....	....	....	2.8	....	....
				2	....	18.07	77.27	4.66	.48	....	....	....	....	....	....	....
				3	....	18.95	81.05	....	.50	....	....	....	....	....	....	....

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WEST VIRGINIA—Continued.																
MERCER COUNTY—continued.																
Weyanoke; Weyanoke No. 1 mine; Pocahontas No. 3 bed (face of room 11, off left entry 9, off main heading, 4-foot 1½-inch bed, 3-foot 11-inch cut).	376	14224	A	1	2.57	18.66	75.35	3.42	.56	......	......	......	......	3.0	......	......
				2	......	19.15	77.34	3.51	.57	......	......	......	......	......	......	......
				3	......	19.85	80.15	......	.59	......	......	......	......	......	......	......
Same (face of main air course; 4-foot ½-inch bed, 3-foot 10-inch cut).	376	14225	A	1	2.74	18.81	74.42	4.03	.60	......	......	......	......	2.1	......	......
				2	......	19.34	76.52	4.14	.62	......	......	......	......	......	......	......
				3	......	20.18	79.82	......	.65	......	......	......	......	......	......	......
Same (face of room 22, off left cross heading 8, 4-foot 6-inch bed, 4-foot 3-inch cut).	376	14226	A	1	3.25	17.33	75.40	4.02	.63	......	......	......	......	2.6	......	......
				2	......	17.91	77.93	4.16	.65	......	......	......	......	......	......	......
				3	......	18.69	81.31	......	.68	......	......	......	......	......	......	......
Same (face of room 6, off left entry 6, 4-foot 3½-inch bed, 4-foot cut).	376	14228	A	1	3.22	17.84	75.47	3.47	.59	......	......	......	......	2.5	......	......
				2	......	18.43	77.98	3.59	.61	......	......	......	......	......	......	......
				3	......	19.12	80.88	......	.63	......	......	......	......	......	......	......
Weyanoke No. 2 mine, Pocahontas No. 3 bed (face of right entry 3, off main entry, 4-foot bed, 3-foot 11-inch cut).	376	14227	A	1	3.10	18.06	75.63	3.21	.64	......	......	......	......	2.5	......	......
				2	......	18.64	78.05	3.31	.66	......	......	......	......	......	......	......
				3	......	19.28	80.72	......	.68	......	......	......	......	......	......	......
Same (pillar of last crosscut in room 7, off left butt entry 2; 4-foot 4-inch bed, 3-foot 11-inch cut).	376	14230	A	1	2.74	17.84	75.48	3.94	.63	......	......	......	......	2.0	8,186	14.735
				2	......	18.34	77.61	4.05	.65	......	......	......	......	......	8,417	15,151
				3	......	19.11	80.89	......	.68	......	......	......	......	......	8,772	15,790
Same (composite of samples 14224, 14225, 14226, 14227, and 14228).	376	14229	A	1	2.97	17.72	75.68	3.63	.65	4.52	85.26	1.16	4.78	2.3	8,167	14,701
				2	......	18.26	78.00	3.74	.67	4.32	87.87	1.20	2.20	......	8,417	15,151
				3	......	18.97	81.03	......	.70	4.49	91.29	1.25	2.27	......	8,744	15,739
MONONGALIA COUNTY.																
Richard, ½ mile northeast of; Elkins No. 1 mine, Upper Freeport bed (face of fifth right "flat," 4,200 feet northeast of mine mouth, 4-foot ¾-inch bed, 3-foot 10½-inch cut).	377	W19475	A	1	2.2	28.7	62.1	7.0	.80	......	......	......	......	......	7,828	14,090
				2	......	29.4	63.4	7.2	.80	......	......	......	......	......	8,006	14,410
				3	......	31.7	68.3	......	.86	......	......	......	......	......	8,628	15,530
Same (face of butt entry 8 off right entry 5, 700 feet from main entry, 3-foot 7½-inch bed, 3-foot 6-inch cut).	377	W19476	A	1	2.6	27.2	61.9	8.3	.90	......	......	......	......	......	7,622	13,720
				2	......	27.9	63.6	8.5	.95	......	......	......	......	......	7,828	14,090
				3	......	30.5	69.5	......	1.04	......	......	......	......	......	8,556	15,400

Winding Gulf No. 1 mine, Beckley bed (face of at; room 14, off left entry 1, off main right heading, 4-foot 4-inch bed, 4-foot 1-inch cut).	384	14368	A	1	2.68	17.71	76.62	2.99	.45	......	......	......	......	2.0	......	......
				2	......	18.20	78.73	3.07	.46	......	......	......	......	......	......	......
				3	......	18.78	81.22	......	.47	......	......	......	......	......	......	......
Same (face of air course of west entry, 4-foot 4-inch bed, 4-foot 1-inch cut).	384	14369	A	1	2.53	18.68	76.17	2.62	.46	......	......	......	......	1.9	......	......
				2	......	19.17	78.14	2.69	.47	......	......	......	......	......	......	......
				3	......	19.70	80.30	......	.48	......	......	......	......	......	......	......
Same (face of main right heading, 4-foot 9-inch bed, 4-foot 5-inch cut).	384	14370	A	1	3.38	16.79	76.56	3.27	.46	......	......	......	......	2.7	......	......
				2	......	17.38	79.24	3.38	.48	......	......	......	......	......	......	......
				3	......	17.99	82.01	......	.50	......	......	......	......	......	......	......
Same (composite of samples 14368, 14369, and 14370).	384	14371	A	1	2.87	17.77	76.44	2.92	.48	4.65	84.95	1.49	5.51	2.2	8,253	14,855
				2	......	18.29	78.70	3.01	.49	4.46	87.46	1.53	3.05	......	8,496	15,293
				3	......	18.86	81.14	......	.51	4.60	90.17	1.58	3.14	......	8,759	15,766
1 mile from; Winding Gulf No. 2 mine, Beckley bed (pillar at break-through to right heading, 4-foot 1-inch bed, 3-foot 9-inch cut).	384	14372	A	1	1.55	17.86	77.79	2.80	.50	......	......	......	......	.9	......	......
				2	......	18.14	79.02	2.84	.51	......	......	......	......	......	......	......
				3	......	18.67	81.33	......	.52	......	......	......	......	......	......	......
Same (face of left heading 2, 4-foot 11-inch bed, 4-foot 8-inch cut).	384	14373	A	1	2.61	17.27	77.47	2.65	.49	......	......	......	......	1.9	......	......
				2	......	17.73	79.55	2.72	.50	......	......	......	......	......	......	......
				3	......	18.23	81.77	......	.51	......	......	......	......	......	......	......
Same (composite of samples 14372 and 14373).....	384	14374	A	1	2.17	17.39	77.77	2.67	.50	4.69	86.28	1.51	4.35	1.4	8,326	14,987
				2	......	17.78	79.49	2.73	.51	4.55	88.20	1.54	2.47	......	8,511	15,320
				3	......	18.28	81.72	......	.52	4.68	90.68	1.58	2.54	......	8,750	15,750
Wood Bay; McAlpin No. 1 mine, Beckley bed (face of second panel, off left heading 3, off second main entry, 5-foot 4½-inch bed and cut).	385	14301	A	1	1.91	17.51	75.17	5.41	.75	......	......	......	......	1.3	......	......
				2	......	17.85	76.63	5.52	.76	......	......	......	......	......	......	......
				3	......	18.89	81.11	......	.80	......	......	......	......	......	......	......
Same (face of second main air course, 5-foot 3-inch bed and cut).	385	14302	A	1	2.58	17.78	74.64	5.00	.53	......	......	......	......	1.8	......	......
				2	......	18.25	76.62	5.13	.54	......	......	......	......	......	......	......
				3	......	19.24	80.76	......	.57	......	......	......	......	......	......	......
Same (face of room 10, second panel, left entry 2, 6-foot 3-inch bed and cut).	385	14303	A	1	2.35	17.75	75.55	4.35	.60	......	......	......	......	1.7	......	......
				2	......	18.18	77.37	4.45	.61	......	......	......	......	......	......	......
				3	......	19.03	80.97	......	.64	......	......	......	......	......	......	......
Same (face of room 3, first panel, left entry 3, 5-foot 3½-inch bed and cut).	385	14304	A	1	2.39	18.40	75.66	3.55	.62	......	......	......	......	1.8	......	......
				2	......	18.85	77.51	3.64	.64	......	......	......	......	......	......	......
				3	......	19.56	80.44	......	.66	......	......	......	......	......	......	......
Same (pillar of main heading 1 between right entries 3 and 4, 4-foot 6½-inch bed, 4-foot 2½-inch cut).	385	14305	A	1	2.05	17.96	77.23	2.76	.52	......	......	......	......	1.4	......	......
				2	......	18.34	78.84	2.82	.53	......	......	......	......	......	......	......
				3	......	18.87	81.13	......	.55	......	......	......	......	......	......	......
Same (face of second panel, off right heading 2, 4-foot 3½-inch bed, 3-foot 11-inch cut).	385	14306	A	1	1.65	17.80	77.72	2.83	.52	......	......	......	......	1.1	......	......
				2	......	18.10	79.02	2.88	.53	......	......	......	......	......	......	......
				3	......	18.64	81.36	......	.55	......	......	......	......	......	......	......
Same (face of fourth panel, off right heading 2, 4-foot 3½-inch bed, 4-foot cut).	385	14307	A	1	1.87	17.73	78.06	2.34	.62	......	......	......	......	1.3	......	......
				2	......	18.07	79.55	2.38	.63	......	......	......	......	......	......	......
				3	......	18.51	81.49	......	.65	......	......	......	......	......	......	......
Same (pillar of air course, near right entry 2, 4-foot 4½-inch bed, 4-foot cut).	385	14308	A	1	2.26	17.92	77.40	2.42	.56	......	......	......	......	1.6	......	......
				2	......	18.33	79.19	2.48	.57	......	......	......	......	......	......	......
				3	......	18.80	81.20	......	.58	......	......	......	......	......	......	......
Same (composite of samples 14301–14308).........	386	14309	A	1	2.20	17.28	77.05	3.52	.59	4.61	84.87	1.58	4.83	1.5	8,188	14,738
				2	......	17.62	78.78	3.60	.60	4.47	86.78	1.62	2.98	......	8,372	15,070
				3	......	18.28	81.72	......	.62	4.64	90.02	1.68	3.04	......	8,684	15,631

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WEST VIRGINIA—Continued.																
RANDOLPH COUNTY.																
Mill Creek, 6 miles south of; Tolbert and Spiker mine, Sewell (?) bed (in entry, about 100 feet north of mine mouth, about 40 feet from outcrop, 4-foot bed, 3-foot 7-inch cut).	386	13561	B	1	5.03	25.45	58.67	10.85	.49	......	......	......	......	3.4	......	......
				2	......	26.80	61.77	11.43	.52	......	......	......	......	......	......	......
				3	......	30.26	69.74	......	.59	......	......	......	......	......	......	......
Spruce, 5 miles from, and about 9 miles southwest of Cheat Bridge; Hopkins mine, Sewell (?) bed (in mine, 1,075 feet southwest of mine mouth, 4-foot 7-inch bed).	386	13601	B	1	2.72	28.71	55.10	13.47	.96	4.74	73.22	1.09	6.52	1.9	7,192	12,946
				2	......	29.51	56.64	13.85	.99	4.56	75.27	1.12	4.21	......	7,393	13,307
				3	......	34.26	65.74	......	1.15	5.29	87.37	1.30	4.89	......	8,582	15,448
WYOMING.																
CONVERSE COUNTY.																
Douglas, 50 miles north of; sec. 33, T. 40 N., R. 72 W., outcrop, Lower Burned bed (6-foot 5-inch bed, 5-foot 7-inch cut).	387	*11442	B	1	27.44	30.91	33.20	8.45	.36	......	......	......	......	19.6	4,372	7,870
				2	......	42.60	45.75	11.65	.50	......	......	......	......	......	6,025	10,845
				3	......	48.22	51.78	......	.57	......	......	......	......	......	6,820	12,276
Glenrock, 20 miles north of; sec. 5, T. 37 N., R. 75 W., country bank (face of pit, 12-foot 8-inch bed, 5-foot cut).	387	*11048	B	1	28.08	31.63	35.67	4.62	.45	6.55	48.32	.69	39.37	14.3	4,639	8,350
				2	......	43.98	49.60	6.42	.63	4.77	67.18	.96	20.04	......	6,450	11,610
				3	......	47.00	53.00	......	.67	5.10	71.79	1.03	21.41	......	6,892	12,406
Inez, 1½ miles south of; sec. 16, T. 33 N., R. 73 W.; Diamond mine (face of entry, 450 feet from mine mouth, 4-foot 8-inch bed and cut).	387	*14781	B	1	25.55	32.73	30.33	11.39	1.25	......	......	......	......	11.2	4,370	7,866
				2	......	43.96	40.74	15.30	1.68	......	......	......	......	......	5,870	10,566
				3	......	51.90	48.10	......	1.98	......	......	......	......	......	6,930	12,474
1 mile south of; NW. ¼ sec. 16, T. 33 N. (?), R. 73 W.; Inez mine (at end of entry, 400 feet northwest of end of slope which is 120 feet northeast of mine mouth, 7-foot 8-inch bed, 5-foot 10-inch cut).	388	*14754	B	1	27.88	32.10	31.70	8.32	.71	6.35	45.34	.73	38.55	15.7	4,328	7,790
				2	......	44.51	43.95	11.54	.98	4.51	62.87	1.01	19.09	......	6,001	10,802
				3	......	50.32	49.68	......	1.11	5.10	71.07	1.14	21.58	......	6,784	12,211
Lost Spring, 9 miles west of; sec. 11, T. 32 N., R. 69 W.; Fred Haynes prospect (face of main entry, 50 feet from entry mouth).	388	*10711	B	1	24.80	32.90	36.46	5.84	1.18	......	......	......	......	7.6	4,612	8,302
				2	......	43.75	48.48	7.77	1.57	......	......	......	......	......	6,133	11,039
				3	......	47.43	52.57	......	1.70	......	......	......	......	......	6,649	11,968
17 miles northeast of; sec. 13, T. 34 N., R. 67 W.; Harney Creek mine (at end of main entry, 50 feet from mouth of entry, 5½-foot bed, 4-foot 11-inch cut).	389	*10911	B	1	29.87	28.06	34.71	7.36	.79	......	......	......	......	16.6	4,258	7,664
				2	......	40.01	49.50	10.49	1.13	......	......	......	......	......	6,071	10,928
				3	......	44.70	55.30	......	1.26	......	......	......	......	......	6,782	12,208

2 miles northwest of; sec. 36, T. 33 N., R. 68 W.; Onyon mine (room 15, off north entry 1, 1,800 feet from mine mouth).	389	*10740	B	1	27.91	27.07	36.73	8.29	.89	6.25	47.47	.80	36.30	10.0	4,403	7,927
				2	....	37.55	50.95	11.50	1.23	4.37	65.85	1.11	15.94	....	6,109	10,996
				3	....	42.43	57.57	....	1.39	4.94	74.40	1.25	18.02	....	6,903	12,425
35 miles north of; sec. 8, T. 37 N., R. 68 W.; prospect, D bed (face of open cut, 4-foot 4-inch bed).	389	*11447	B	1	27.78	29.38	38.56	4.28	.27	....	....	....	....	16.8	4,673	8,411
				2	....	40.68	53.39	5.93	.37	....	....	....	....	....	6,471	11,648
				3	....	43.24	56.76	....	.39	....	....	....	....	....	6,879	12,382
8 miles north of; sec. 35, T. 34 N., R. 68 W.; Rosin mine (face of left entry 1, about 1,000 feet from the mine mouth, 5-foot 1-inch bed, 4-foot 9-inch cut).	390	*10775	B	1	27.65	26.70	35.66	9.99	1.03	6.26	45.75	.68	36.29	15.7	4,338	7,808
				2	....	36.90	49.29	13.81	1.42	4.42	63.24	.94	16.17	....	5,996	10,793
				3	....	42.81	57.19	....	1.65	5.13	73.37	1.09	18.76	....	6,957	12,523
8 miles northwest of; Sunset mine (face of main entry, 500 feet from mine mouth, 5-foot 3½-inch bed, 4-foot 8-inch cut).	390	*10835	B	1	24.04	28.44	34.87	12.65	.61	....	....	....	....	9.7	4,268	7,682
				2	....	37.44	45.91	16.65	.80	....	....	....	....	....	5,619	10,114
				3	....	44.92	55.08	....	.96	....	....	....	....	....	6,742	12,136
CROOK COUNTY.																
Sundance, 7½ miles west of; SE. ¼ NW. ¼ sec. 24, T. 51 N., R. 64 W.; Belshe mine (end of room 150 feet long turned east from back entry, about 275 feet from mine mouth; 5-foot 3½-inch bed, 4-foot 11¼-inch cut).	391	15713	B	1	20.24	36.35	34.08	9.33	5.25	....	....	....	....	15.7	5,192	9,346
				2	....	45.58	42.72	11.70	6.58	....	....	....	....	....	6,510	11,718
				3	....	51.62	48.38	....	7.45	....	....	....	....	....	7,373	13,271
Same (in last crosscut, 48 feet from front entry, crosscut turn 336 feet from mouth of mine, 4-foot 3½-inch bed, 3-foot 6-inch cut).	391	15714	B	1	19.34	35.35	34.24	11.07	4.38	5.90	51.02	.75	26.88	13.7	5,110	9,198
				2	....	43.83	42.45	13.72	5.43	4.65	63.25	.93	12.02	....	6,335	11,403
				3	....	50.80	49.20	....	6.29	5.39	73.31	1.08	13.93	....	7,342	13,216
Same (position and bed same as No. 15714, 4-foot 3½-inch cut).	391	15715	B	1	17.16	34.08	32.57	16.19	5.18	....	....	....	....	12.4	4,891	8,804
				2	....	41.14	39.32	19.54	6.25	....	....	....	....	....	5,904	10,627
				3	....	51.13	48.87	....	7.77	....	....	....	....	....	7,338	13,208
FREEMONT COUNTY.																
Hudson, 1 mile west of; sec. 11, T. 1 S., R. 2 E.; Hickey mine (room 3, off south entry, 300 feet from mine mouth, 3-foot 4-inch bed and cut).	391	*17247	A	1	23.07	33.07	39.66	4.20	.69	6.22	55.13	1.40	32.36	5.6	5,283	9,509
				2	....	42.99	51.55	5.46	.90	4.76	71.66	1.82	15.40	....	6,867	12,361
				3	....	45.47	54.53	....	.95	5.04	75.80	1.93	16.28	....	7,264	13,075
1½ miles north of; sec. 2, T. 2 S., R. 2 E.; Indian mine (fifth west back entry, one-fourth mile southwest of mine mouth, 6-foot 6-inch bed, 3-foot 6-inch cut).	392	*13178	B	1	20.88	31.90	39.16	8.06	.51	....	....	....	....	14.0	5,134	9,241
				2	....	40.32	49.49	10.19	.64	....	....	....	....	....	6,489	11,680
				3	....	44.90	55.10	....	.71	....	....	....	....	....	7,226	13,007
Same (in main entry, about 900 feet from mouth of mine, 7-foot bed, 5-foot 6-inch cut).	392	*13179	B	1	20.39	33.07	40.69	5.85	.58	....	....	....	....	11.2	5,307	9,553
				2	....	41.54	51.11	7.35	.73	....	....	....	....	....	6,666	11,999
				3	....	44.83	55.17	....	.79	....	....	....	....	....	7,195	12,951
Same (face of room 17, off 00 entry, 7-foot 7½-inch bed and cut).	392	*10838	A	1	22.18	31.85	42.53	3.44	.51	....	....	....	....	9.2	....	....
				2	....	40.93	54.65	4.42	.66	....	....	....	....	....	....	....
				3	....	42.82	57.18	....	.69	....	....	....	....	....	....	....
Same (face of west entry 4, 7-foot 7½-inch bed, 6-foot 3-inch cut).	392	*10839	A	1	20.98	30.93	43.14	4.95	.44	....	....	....	....	8.2	....	....
				2	....	39.14	54.60	6.26	.56	....	....	....	....	....	....	....
				3	....	41.75	58.25	....	.60	....	....	....	....	....	....	....
Same (in room (about No. 30) off west entry 2, 7-foot 10-inch bed, 7-foot 2-inch cut).	392	*10840	A	1	21.28	31.15	40.69	6.88	.52	....	....	....	....	8.0	....	....
				2	....	39.57	51.69	8.74	.66	....	....	....	....	....	....	....
				3	....	43.36	56.64	....	.72	....	....	....	....	....	....	....
Same (face of room 4, off east entry 3, 7-foot 2-inch bed, 6-foot 6-inch cut).	392	*10841	A	1	21.20	29.87	41.72	7.21	.52	....	....	....	....	8.3	....	....
				2	....	37.91	52.94	9.15	.66	....	....	....	....	....	....	....
				3	....	41.73	58.27	....	.73	....	....	....	....	....	....	....

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WYOMING—Continued.																
FREEMONT COUNTY—continued.																
Hudson, 1½ miles north of; sec. 2, T. 2 S., R. 2, E.; Indian mine (face of room 14½, off west entry 2, 7-foot 6-inch bed and cut).	392	*10843	A	1	20.87	31.97	43.43	3.73	.47	6.21	56.74	1.23	31.62	7.8	5,434	9,781
				2		40.40	54.89	4.71	.59	4.92	71.70	1.55	16.53		6,867	12,361
				3		42.40	57.60		.62	5.16	75.24	1.63	17.35		7,206	12,971
Same (composite of samples 10838-10841)	392	*10842	A	1	21.10	31.35	41.75	5.80	.49	6.21	54.33	1.21	31.96	8.4	5,257	9,463
				2		39.73	52.92	7.35	.62	4.90	68.86	1.53	16.74		6,663	11,993
				3		42.88	57.12		.67	5.29	74.32	1.65	18.07		7,191	12,944
5 miles from; SW. ¼ sec. 22, T. 1 S., R. 2 E.; Mitchell mine (in last room off main slope, 40 feet from slope and 500 feet from mouth of slope, 3-foot 4-inch bed, 3-foot 2½-inch cut).	393	*17248	A	1	19.53	34.69	39.57	6.21	.71	6.05	56.03	1.35	29.65	3.8	5,413	9,743
				2		43.11	49.17	7.72	.88	4.82	69.63	1.68	15.27		6,727	12,109
				3		46.72	53.28		.95	5.22	75.46	1.82	16.55		7,290	13,122
4 miles from; sec. 3, T. 33 N., R. 98 W.; Proposia mine, Lander bed (face of north entry 2, 1,800 feet from mine mouth, 17-foot bed, 9-foot 6-inch cut).	393	*17244	A	1	23.38	33.55	38.54	4.53	.66					6.7	5,233	9,419
				2		43.79	50.30	5.91	.86						6,830	12,294
				3		46.54	53.46		.91						7,259	13,066
Same (face of south entry 5, 1,200 feet from mine mouth, 8-foot bed and cut).	393	*17245	A	1	24.70	31.78	39.52	4.00	.54					10.1	5,166	9,290
				2		42.20	52.49	5.31	.72						6,860	12,348
				3		44.57	55.43		.76						7,245	13,041
Same (composite of samples 17244 and 17245)	394	*17246	A	1	23.95	31.67	40.14	4.24	.65	6.59	54.44	1.21	32.87	8.4	5,209	9,376
				2		41.64	52.78	5.58	.85	5.17	71.58	1.59	15.23		6,849	12,328
				3		44.10	55.90		.90	5.48	75.81	1.68	16.13		7,254	13,057
HOT SPRINGS COUNTY.																
Crosby, 2 miles from Kirby; sec. 13, T. 44 N., R. 95 W.; Big Horn mine, Gebo bed. (face of room 5 near east rib, off butt entry 3, off west entry 1, 7-foot 6-inch bed and cut).	394	*15202	A	1	16.59	33.64	46.37	3.40	.58					8.6	6,044	10,879
				2		40.33	55.59	4.08	.70						7,246	13,043
				3		42.04	57.96		.73						7,554	13,597
Same (east rib of room 5, off second butt dip entry, off west entry 2, 50 feet in from entry, 8-foot 5-inch bed, 8-foot 2-inch cut).	394	*15209	A	1	15.98	32.91	43.78	7.33	.62					9.7	5,771	10,388
				2		39.17	52.11	8.72	.74						6,869	12,364
				3		42.91	57.09		.81						7,525	13,545
Same (face of room 6, off first dip butt entry, off west entry 2, 8-foot 6-inch bed, 8-foot 3-inch cut).	394	*15217	A	1	17.24	31.09	46.70	4.97	.52					8.7	5,889	10,606
				2		37.57	56.42	6.01	.63						7,116	12,800
				3		39.97	60.03		.67						7,571	13,628

Same (face of room 9, off east entry 2, 45 feet from entry, 5-foot 3-inch bed and cut).	394	*15219	A	1	16.40	33.78	46.14	3.68	.62	......	......	......	......	9.0	6,029	10,852
				2	......	40.41	55.19	4.40	.74	......	......	......	......	......	7,212	12,982
				3	......	42.27	57.73	......	.77	......	......	......	......	......	7,544	13,579
Same (composite of samples 15202, 15209, 15217, and 15219).	394	*15237	A	1	16.56	33.11	45.49	4.84	.59	6.04	60.64	1.33	26.56	9.0	5,926	10,667
				2	......	39.68	54.52	5.80	.71	5.03	72.68	1.59	14.19	......	7,102	12,784
				3	......	42.12	57.88	......	.75	5.34	77.16	1.69	15.06	......	7,539	13,570
Same (position, bed, and cut same as sample 15202).	394	*15201	A	1	16.34	33.29	46.89	3.48	.58	......	......	......	......	8.6	6,074	10,933
				2	......	39.79	56.05	4.16	.69	......	......	......	......	......	7,260	13,068
				3	......	41.52	58.48	......	.72	......	......	......	......	......	7,575	13,635
Same (position, bed, and cut same as sample 15209).	394	*15210	A	1	16.08	33.00	43.86	7.06	.57	......	......	......	......	10.2	5,789	10,420
				2	......	39.32	52.27	8.41	.68	......	......	......	......	......	6,898	12,416
				3	......	42.93	57.07	......	.74	......	......	......	......	......	7,531	13,556
Same (position, bed, and cut same as sample 15217).	394	*15216	A	1	17.07	32.54	45.66	4.73	.53	......	......	......	......	8.5	5,904	10,627
				2	......	39.24	55.06	5.70	.64	......	......	......	......	......	7,119	12,814
				3	......	41.61	58.39	......	.68	......	......	......	......	......	7,549	13,588
Same (position, bed, and cut same as sample 15219).	394	*15218	A	1	16.46	33.87	45.97	3.70	.60	......	......	......	......	9.2	6,036	10,865
				2	......	40.54	55.03	4.43	.72	......	......	......	......	......	7,225	13,005
				3	......	42.42	57.58	......	.75	......	......	......	......	......	7,560	13,608
Same (composite of samples 15201, 15210, 15216, and 15218).	395	*15236	A	1	16.48	32.91	45.83	4.78	.58	5.97	61.08	1.35	26.24	9.1	5,972	10,750
				2	......	39.40	54.88	5.72	.69	4.96	73.13	1.62	13.88	......	7,150	12,870
				3	......	41.79	58.21	......	.73	5.26	77.57	1.72	14.72	......	7,584	13,651
Same (pillar between rooms 6 and 7, off butt entry 2, off west entry 1, 8-foot 1-inch bed and cut).	394	*15214	A	1	17.20	32.31	46.61	3.88	.61	......	......	......	......	10.2	5,971	10,748
				2	......	39.02	56.29	4.69	.74	......	......	......	......	......	7,211	12,980
				3	......	40.94	59.06	......	.78	......	......	......	......	......	7,566	13,619
Same (position, bed, and cut same as sample 15214).	394	*15215	A	1	17.01	32.54	46.70	3.75	.61	......	......	......	......	9.7	5,970	10,746
				2	......	39.21	56.27	4.52	.74	......	......	......	......	......	7,194	12,949
				3	......	41.06	58.94	......	.78	......	......	......	......	......	7,534	13,561
Same (slack coal, sampled at the mine)	395	*15203	C	1	17.47	32.08	43.41	7.04	.72	......	......	......	......	11.5	5,635	10,143
				2	......	38.87	52.60	8.53	.87	......	......	......	......	......	6,828	12,290
				3	......	42.50	57.50	......	.95	......	......	......	......	......	7,465	13,437
Same (coal from same pile as sample 15203)	395	*15204	C	1	17.30	32.63	43.24	6.83	.70	......	......	......	......	10.9	5,643	10,157
				2	......	39.46	52.28	8.26	.85	......	......	......	......	......	6,824	12,283
				3	......	43.01	56.99	......	.93	......	......	......	......	......	7,438	13,388
Same (slack taken from 17 wagonloads)	395	*15205	C	1	17.60	31.82	44.03	6.55	.69	......	......	......	......	11.5	5,648	10,166
				2	......	38.62	53.43	7.95	.84	......	......	......	......	......	6,854	12,337
				3	......	41.96	58.04	......	.91	......	......	......	......	......	7,446	13,403
Same (slack taken from 20 wagonloads)	395	*15207	C	1	17.88	32.15	42.46	7.51	.67	......	......	......	......	12.1	5,580	10,044
				2	......	39.15	51.71	9.14	.82	......	......	......	......	......	6,795	12,231
				3	......	43.09	56.91	......	.90	......	......	......	......	......	7,479	13,462
Same (slack taken from 18 wagonloads)	395	*15211	C.	1	17.80	31.36	43.18	7.66	.68	......	......	......	......	11.8	5,589	10,060
				2	......	38.15	52.53	9.32	.83	......	......	......	......	......	6,799	12,238
				3	......	42.07	57.93	......	.92	......	......	......	......	......	7,498	13,496
Same (composite of samples 15205, 15207, and 15211).	395	*15234	C.	1	17.85	31.57	43.37	7.21	.64	6.06	57.70	1.26	27.13	11.8	5,610	10,098
				2	......	38.43	52.79	8.78	.78	4.97	70.24	1.53	13.70	......	6,829	12,292
				3	......	42.13	57.87	......	.86	5.45	77.00	1.68	15.01	......	7,487	13,477
Same (slack taken from same wagons as sample 15205).	395	*15206	C.	1	17.75	32.06	44.07	6.12	.70	......	......	......	......	12.0	5,673	10,211
				2	......	38.98	53.58	7.44	.85	......	......	......	......	......	6,897	12,415
				3	......	42.11	57.89	......	.92	......	......	......	......	......	7,452	13,414
Same (slack taken from same wagons as sample 15207).	395	*15208	C.	1	17.81	32.30	41.86	8.03	.70	......	......	......	......	12.0	5,541	9,974
				2	......	39.30	50.93	9.77	.85	......	......	......	......	......	6,742	12,136
				3	......	43.56	56.44	......	.94	......	......	......	......	......	7,472	13,450

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WYOMING—Continued.																
FREEMONT COUNTY—continued.																
Hudson, 1½ miles north of; sec. 2, T. 2 S., R. 2, E.; Indian mine (face of room 14½, off west entry 2, 7-foot 6-inch bed and cut).	392	*10843	A	1	20.87	31.97	43.43	3.73	.47	6.21	56.74	1.23	31.62	7.8	5,434	9,781
				2	....	40.40	54.89	4.71	.59	4.92	71.70	1.55	16.53	....	6,867	12,361
				3	....	42.40	57.60	....	.62	5.16	75.24	1.63	17.35	....	7,206	12,971
Same (composite of samples 10838-10841).........	392	*10842	A	1	21.10	31.35	41.75	5.80	.49	6.21	54.33	1.21	31.96	8.4	5,257	9,463
				2	....	39.73	52.92	7.35	.62	4.90	68.86	1.53	16.74	....	6,663	11,993
				3	....	42.88	57.12	....	.67	5.29	74.32	1.65	18.07	....	7,191	12,944
5 miles from; SW. ¼ sec. 22, T. 1 S., R. 2 E.; Mitchell mine (in last room off main slope, 40 feet from slope and 500 feet from mouth of slope, 3-foot 4-inch bed, 3-foot 2½-inch cut).	393	*17248	A	1	19.53	34.69	39.57	6.21	.71	6.05	56.03	1.35	29.65	3.8	5,413	9,743
				2	....	43.11	49.17	7.72	.88	4.82	69.63	1.68	15.27	....	6,727	12,109
				3	....	46.72	53.28	....	.95	5.22	75.46	1.82	16.55	....	7,290	13,122
4 miles from; sec. 3, T. 33 N., R. 98 W.; Proposia mine, Lander bed (face of north entry 2, 1,800 feet from mine mouth, 17-foot bed, 9-foot 6-inch cut).	393	*17244	A	1	23.38	33.55	38.54	4.53	.66	....	....	....	....	6.7	5,233	9,419
				2	....	43.79	50.30	5.91	.86	....	....	....	....	....	6,830	12,294
				3	....	46.54	53.46	....	.91	....	....	....	....	....	7,259	13,066
Same (face of south entry 5, 1,200 feet from mine mouth, 8-foot bed and cut).	393	*17245	A	1	24.70	31.78	39.52	4.00	.54	....	....	....	....	10.1	5,166	9,299
				2	....	42.20	52.49	5.31	.72	....	....	....	....	....	6,860	12,348
				3	....	44.57	55.43	....	.76	....	....	....	....	....	7,245	13,041
Same (composite of samples 17244 and 17245).....	394	*17246	A	1	23.95	31.67	40.14	4.24	.65	6.59	54.44	1.21	32.87	8.4	5,209	9,376
				2	....	41.64	52.78	5.58	.85	5.17	71.58	1.59	15.23	....	6,849	12,328
				3	....	44.10	55.90	....	.90	5.48	75.81	1.68	16.13	....	7,254	13,057
HOT SPRINGS COUNTY.																
Crosby, 2 miles from Kirby; sec. 13, T. 44 N., R. 95 W.; Big Horn mine, Gebo bed. (face of room 5 near east rib, off butt entry 3, off west entry 1, 7-foot 6-inch bed and cut).	394	*15202	A	1	16.59	33.64	46.37	3.40	.58	....	....	....	....	8.6	6,044	10,879
				2	....	40.33	55.59	4.08	.70	....	....	....	....	....	7,246	13,043
				3	....	42.04	57.96	....	.73	....	....	....	....	....	7,554	13,597
Same (east rib of room 5, off second butt dip entry, off west entry 2, 50 feet in from entry, 8-foot 5-inch bed, 8-foot 2-inch cut).	394	*15209	A	1	15.98	32.91	43.78	7.33	.62	....	....	....	....	9.7	5,771	10,388
				2	....	39.17	52.11	8.72	.74	....	....	....	....	....	6,869	12,364
				3	....	42.91	57.09	....	.81	....	....	....	....	....	7,525	13,545
Same (face of room 6, off first dip butt entry, off west entry 2, 8-foot 6-inch bed, 8-foot 3-inch cut).	394	*15217	A	1	17.24	31.09	46.70	4.97	.52	....	....	....	....	8.7	5,889	10,606
				2	....	37.57	56.42	6.01	.63	....	....	....	....	....	7,116	12,800
				3	....	39.97	60.03	....	.67	....	....	....	....	....	7,571	13,628

Same (face of room 9, off east entry 2, 45 feet from entry, 5-foot 3-inch bed and cut).	394	*15219	A	1	16.40	33.78	46.14	3.68	.62	......	......	......	......	9.0	6,029	10,852
				2	......	40.41	55.19	4.40	.74	......	......	......	......	......	7,212	12,982
				3	......	42.27	57.73	......	.77	......	......	......	......	......	7,544	13,579
Same (composite of samples 15202, 15209, 15217, and 15219).	394	*15237	A	1	16.56	33.11	45.49	4.84	.59	6.04	60.64	1.33	26.56	9.0	5,926	10,667
				2	......	39.68	54.52	5.80	.71	5.03	72.68	1.59	14.19	......	7,102	12,784
				3	......	42.12	57.88	......	.75	5.34	77.16	1.69	15.06	......	7,539	13,570
Same (position, bed, and cut same as sample 15202).	394	*15201	A	1	16.34	33.29	46.89	3.48	.58	......	......	......	......	8.6	6,074	10,933
				2	......	39.79	56.05	4.16	.69	......	......	......	......	......	7,260	13,068
				3	......	41.52	58.48	......	.72	......	......	......	......	......	7,575	13,635
Same (position, bed, and cut same as sample 15209).	394	*15210	A	1	16.08	33.00	43.86	7.06	.57	......	......	......	......	10.2	5,789	10,420
				2	......	39.32	52.27	8.41	.68	......	......	......	......	......	6,898	12,416
				3	......	42.93	57.07	......	.74	......	......	......	......	......	7,531	13,556
Same (position, bed, and cut same as sample 15217).	394	*15216	A	1	17.07	32.54	45.66	4.73	.53	......	......	......	......	8.5	5,904	10,627
				2	......	39.24	55.06	5.70	.64	......	......	......	......	......	7,119	12,814
				3	......	41.61	58.39	......	.68	......	......	......	......	......	7,549	13,588
Same (position, bed, and cut same as sample 15219).	394	*15218	A	1	16.46	33.87	45.97	3.70	.60	......	......	......	......	9.2	6,036	10,865
				2	......	40.54	55.03	4.43	.72	......	......	......	......	......	7,225	13,005
				3	......	42.42	57.58	......	.75	......	......	......	......	......	7,560	13,608
Same (composite of samples 15201, 15210, 15216, and 15218).	395	*15236	A	1	16.48	32.91	45.83	4.78	.58	5.97	61.08	1.35	26.24	9.1	5,972	10,750
				2	......	39.40	54.88	5.72	.69	4.96	73.13	1.62	13.88	......	7,150	12,870
				3	......	41.79	58.21	......	.73	5.26	77.57	1.72	14.72	......	7,584	13,651
Same (pillar between rooms 6 and 7, off butt entry 2, off west entry 1, 8-foot 1-inch bed and cut).	394	*15214	A	1	17.20	32.31	46.61	3.88	.61	......	......	......	......	10.2	5,971	10,748
				2	......	39.02	56.29	4.69	.74	......	......	......	......	......	7,211	12,980
				3	......	40.94	59.06	......	.78	......	......	......	......	......	7,566	13,619
Same (position, bed, and cut same as sample 15214).	394	*15215	A	1	17.01	32.54	46.70	3.75	.61	......	......	......	......	9.7	5,970	10,746
				2	......	39.21	56.27	4.52	.74	......	......	......	......	......	7,194	12,949
				3	......	41.06	58.94	......	.78	......	......	......	......	......	7,534	13,561
Same (slack coal, sampled at the mine)	395	*15203	C	1	17.47	32.08	43.41	7.04	.72	......	......	......	......	11.5	5,635	10,143
				2	......	38.87	52.60	8.53	.87	......	......	......	......	......	6,828	12,290
				3	......	42.50	57.50	......	.95	......	......	......	......	......	7,465	13,437
Same (coal from same pile as sample 15203)	395	*15204	C	1	17.30	32.63	43.24	6.83	.70	......	......	......	......	10.9	5,643	10,157
				2	......	39.46	52.28	8.26	.85	......	......	......	......	......	6,824	12,283
				3	......	43.01	56.99	......	.93	......	......	......	......	......	7,438	13,388
Same (slack taken from 17 wagonloads)	395	*15205	C	1	17.60	31.82	44.03	6.55	.69	......	......	......	......	11.5	5,648	10,166
				2	......	38.62	53.43	7.95	.84	......	......	......	......	......	6,854	12,337
				3	......	41.96	58.04	......	.91	......	......	......	......	......	7,446	13,403
Same (slack taken from 20 wagonloads)	395	*15207	C	1	17.88	32.15	42.46	7.51	.67	......	......	......	......	12.1	5,580	10,044
				2	......	39.15	51.71	9.14	.82	......	......	......	......	......	6,795	12,231
				3	......	43.09	56.91	......	.90	......	......	......	......	......	7,479	13,462
Same (slack taken from 18 wagonloads)	395	*15211	C.	1	17.80	31.36	43.18	7.66	.68	......	......	......	......	11.8	5,589	10,060
				2	......	38.15	52.53	9.32	.83	......	......	......	......	......	6,799	12,238
				3	......	42.07	57.93	......	.92	......	......	......	......	......	7,498	13,496
Same (composite of samples 15205, 15207, and 15211).	395	*15234	C.	1	17.85	31.57	43.37	7.21	.64	6.06	57.70	1.26	27.13	11.8	5,610	10,098
				2	......	38.43	52.79	8.78	.78	4.97	70.24	1.53	13.70	......	6,829	12,292
				3	......	42.13	57.87	......	.86	5.45	77.00	1.68	15.01	......	7,487	13,477
Same (slack taken from same wagons as sample 15205).	395	*15206	C.	1	17.75	32.06	44.07	6.12	.70	......	......	......	......	12.0	5,673	10,211
				2	......	38.98	53.58	7.44	.85	......	......	......	......	......	6,897	12,415
				3	......	42.11	57.89	......	.92	......	......	......	......	......	7,452	13,414
Same (slack taken from same wagons as sample 15207).	395	*15208	C.	1	17.81	32.30	41.86	8.03	.70	......	......	......	......	12.0	5,541	9,974
				2	......	39.30	50.93	9.77	.85	......	......	......	......	......	6,742	12,136
				3	......	43.56	56.44	......	.94	......	......	......	......	......	7,472	13,450

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WYOMING—Continued.																
HOT SPRINGS COUNTY—continued.																
Crosby, 2 miles from Kirby; sec. 13, T. 44 N., R. 95 W.; Big Horn mine, Gebo bed (slack taken from same wagons as sample 15211).	395	*15212	C.	1	17.88	31.52	42.38	8.22	.65	......	......	......	......	11.7	5,557	10,003
				2	......	38.38	51.61	10.01	.79	......	......	......	......	......	6,767	12,181
				3	......	42.65	57.35	......	.88	......	......	......	......	......	7,519	13,534
Same (composite of samples 15206, 15208, and 15212).	395	*15235	C.	1	17.87	31.26	43.48	7.39	.66	5.99	57.41	1.28	27.27	11.9	5,590	10,062
				2	......	38.06	52.94	9.00	.80	4.87	69.90	1.56	13.87	......	6,806	12,251
				3	......	41.82	58.18	......	.88	5.35	76.81	1.71	15.25	......	7,479	13,462
Kirby, 2 miles from; sec. 11, T. 44 N.; R. 95 W.; Gebo mine, Gebo bed (face of east entry 4; 225 feet from butt entry 2; 7-foot 10-inch bed and cut).	395	*15277	A.	1	16.66	31.88	47.03	4.43	.62	......	......	......	......	10.5	6,005	10,809
				2	......	38.25	56.43	5.32	.74	......	......	......	......	......	7,205	12,969
				3	......	40.40	59.60	......	.78	......	......	......	......	......	7,610	13,698
Same (face of room 8, off second east butt entry, off entry 5, 8-foot 9-inch bed and cut).	396	*15278	A.	1	15.46	33.50	47.58	3.46	.66	......	......	......	......	7.6	6,189	11,140
				2	......	39.63	56.28	4.09	.78	......	......	......	......	......	7,321	13,178
				3	......	41.32	58.68	......	.81	......	......	......	......	......	7,633	13,739
Same (face of room 7, off first east butt entry, off fifth level, 9-foot 8-inch bed and cut).	396	*15279	A.	1	15.27	33.64	46.73	4.36	.56	......	......	......	......	9.1	6,106	10,991
				2	......	39.70	55.15	5.15	.66	......	......	......	......	......	7,206	12,971
				3	......	41.86	58.14	......	.70	......	......	......	......	......	7,597	13,675
Same (face of east entry 3; 400 feet from butt entry 2; 9-foot 2-inch bed and cut).	396	*15280	A.	1	16.30	33.57	46.95	3.18	.52	......	......	......	......	9.6	6,098	10,976
				2	......	40.11	56.09	3.80	.62	......	......	......	......	......	7,285	13,113
				3	......	41.69	58.31	......	.64	......	......	......	......	......	7,573	13,631
Same (composite of samples 15277, 15278, 15279, and 15280).	396	*15283	A.	1	15.86	33.01	47.39	3.74	.59	6.06	62.03	1.29	26.29	9.2	6,102	10,984
				2	......	39.23	56.33	4.44	.70	5.11	73.72	1.53	14.50	......	7,252	13,054
				3	......	41.05	58.95	......	.73	5.35	77.15	1.60	15.17	......	7,589	13,660
Same (face of west entry 3; 300 feet from main slope; 7-foot 11-inch bed and cut).	396	*15281	A.	1	16.35	32.93	47.72	3.00	.43	......	......	......	......	8.2	6,120	11,016
				2	......	39.37	57.04	3.59	.51	......	......	......	......	......	7,316	13,169
				3	......	40.83	59.17	......	.53	......	......	......	......	......	7,588	13,658
Same (barrier pillar between room 1 west side and back entry, off second level, 6-foot 9-inch bed and cut).	396	*15282	A.	1	17.06	32.10	47.75	3.09	.43	......	......	......	......	10.0	6,043	10,877
				2	......	38.70	57.57	3.73	.52	......	......	......	......	......	7,286	13,115
				3	......	40.20	59.80	......	.54	......	......	......	......	......	7,568	13,622
Same (pillar between west entry 2 and back entry, 375 feet beyond butt entry 3, about 1,750 feet from main slope, 5-foot 9-inch bed and cut).	396	*15342	A	1	16.64	32.92	46.68	3.76	.46	......	......	......	......	8.3	6,005	10,809
				2	......	39.49	56.00	4.51	.55	......	......	......	......	......	7,204	12,967
				3	......	41.35	58.65	......	.58	......	......	......	......	......	7,544	13,579

Same (position, bed, and cut same as No. 15342)..	396	*15343	A	1	16.68	33.23	46.34	3.75	.43	......	......	......	......	8.2	5,995	10,791
				2	......	39.88	55.62	4.50	.52	......	......	......	......	......	7.195	12,951
				3	......	41.76	58.24	......	.54	......	......	......	......	......	7,534	13,561
Same (pillar between rooms 1 and 2, off first west butt entry, off east entry 2, about 400 feet from main slope; 6-foot 1-inch bed and cut).	396	*15344	A	1	17.36	33.91	45.90	2.83	.47	......	......	......	......	8.7	6,019	10,834
				2	......	41.03	55.55	3.42	.57	......	......	......	......	......	7,284	13,111
				3	......	42.48	57.52	......	.59	......	......	......	......	......	7,542	13,576
Same (position, bed, and cut same as No. 15344)..	396	*15345	A	1	17.27	33.11	46.87	2.75	.46	......	......	......	......	9.1	6,035	10,863
				2	......	40.02	56.66	3.32	.56	......	......	......	......	......	7,295	13,131
				3	......	41.39	58.61	......	.58	......	......	......	......	......	7,545	13,581
Same (pillar between pitch rooms 10 and 11, off west entry 1, off butt entry 2; 6-foot 5-inch bed and cut).	396	*15346	A	1	16.55	33.40	46.82	3.23	.42	......	......	......	......	6.9	6,012	10,822
				2	......	40.02	56.11	3.87	.50	......	......	......	......	......	7,204	12,967
				3	......	41.63	58.37	......	.52	......	......	......	......	......	7,494	13,489
Same (position, bed, and cut same as No. 15346)..	396	*15347	A	1	16.63	33.27	46.96	3.14	.42	......	......	......	......	6.9	6,029	10,852
				2	......	39.91	56.32	3.77	.50	......	......	......	......	......	7,232	13,018
				3	......	41.47	58.53	......	.52	......	......	......	......	......	7,515	13,527
Same (near face on pillar between west entry 1 and back entry, 2,100 feet from main slope, 6-foot 7-inch bed and cut).	396	*15348	A	1	16.87	32.83	46.77	3.53	.52	......	......	......	......	6.5	5,950	10,710
				2	......	39.49	56.26	4.25	.63	......	......	......	......	......	7,157	12,883
				3	......	41.24	58.76	......	.66	......	......	......	......	......	7,475	13,455
Same (position, bed, and cut same as No. 15348)..	396	*15349	A	1	16.91	33.01	46.71	3.37	.51	......	......	......	......	7.3	5,960	10,728
				2	......	39.73	56.21	4.06	.61	......	......	......	......	......	7,173	12,911
				3	......	41.41	58.59	......	.64	......	......	......	......	......	7,476	13,457
Same (composite of 6 samples of slack taken from cars while being loaded).................	396	*15475	C	1	17.47	31.99	45.29	5.25	.66	6.10	60.06	1.32	26.61	10.3	5,870	10,566
				2	......	38.76	54.88	6.36	.80	5.04	72.77	1.60	13.43	......	7,113	12,803
				3	......	41.39	58.61	......	.85	5.38	77.71	1.71	14.35	......	7,596	13,673
Same (composite of 6 samples of slack taken from cars while being loaded)	396	*15482	C	1	17.08	32.51	45.36	5.05	.62	6.07	60.71	1.29	26.26	10.7	5,876	10,577
				2	......	39.21	54.70	6.09	.75	5.03	73.22	1.56	13.35	......	7,086	12,755
				3	......	41.75	58.25	......	.80	5.36	77.96	1.66	14.22	......	7,545	13,581
Same (slack from a car shipped to Bureau of Mines station at Pittsburgh for testing purposes).	396	*15687	C	1	16.58	31.97	46.05	5.40	.64	5.93	60.18	1.33	26.52	9.3	5,894	10,609
				2	......	38.33	55.20	6.47	.77	4.90	72.14	1.59	14.13	......	7,066	12,719
				3	......	40.98	59.02	......	.82	5.24	77.13	1.70	15.11	......	7,555	13,599
Same (slack from a car shipped to Bureau of Mines station at Pittsburgh for testing purposes).	396	*16102	C	1	16.67	33.30	45.24	4.79	.69	6.01	60.62	1.36	26.53	11.3	5,883	10,589
				2	......	39.96	54.29	5.75	.83	4.99	72.74	1.63	14.06	......	7,060	12,708
				3	......	42.40	57.60	......	.88	5.29	77.18	1.73	14.92	......	7,491	13,484
Meeteetse, 18 miles southeast of; sec. 2, T. 46 N., R. 99 W.; Dickie No. 1 prospect (east rib of west entry, 25 feet from mouth, 4-foot bed and cut).	397	14679	B	1	14.75	37.77	38.08	9.40	.70	......	......	......	......	0.9	5,587	10,057
				2	......	44.30	44.67	11.03	.82	......	......	......	......	......	6,554	11,797
				3	......	49.79	50.21	......	.92	......	......	......	......	......	7,367	13,261
19 miles southeast of; E. ½ sec. 26, T. 46 N., R. 99 W.; Mayfield No. 2 prospect (face of new drift entry, 30 feet from entry mouth, 30-foot bed, 6-foot cut).	397	*14756	B	1	10.67	37.99	43.99	7.35	.35	......	......	......	......	3.4	6,151	11,072
				2	......	42.53	49.24	8.23	.39	......	......	......	......	......	6,885	12,393
				3	......	46.34	53.66	......	.42	......	......	......	......	......	7,503	13,505
JOHNSON COUNTY.																
Buffalo, 18 miles southeast of; prospect, B bed (10-foot 9½-inch bed, 3-foot 4-inch cut).	398	10683	B	1	28.81	......	......	6.67	.56	......	......	......	......	19.6	4,406	7,931
				2	......	......	......	9.37	.79	......	......	......	......	......	6,189	11,140
				3	......	......	......	......	.87	......	......	......	......	......	6,829	12,292
Casper, 75 miles north of; sec. 23, T. 44 N., R. 81 W.; prospect (6-foot 3-inch bed, 42-inch cut).	398	10728	B	1	23.61	......	......	7.76	.68	......	......	......	......	11.8	4,692	8,446
				2	......	......	......	10.16	.89	......	......	......	......	......	6,141	11,054
				3	......	......	......	......	.99	......	......	......	......	......	6,836	12,305
60 miles north of; sec. 36, T. 43 N., R. 79 W.; prospect (13-foot 11-inch bed, 43-inch cut)	399	*10804	B	1	18.82	35.75	37.88	7.55	.57	......	......	......	......	8.1	5,087	9,157
				2	......	44.04	46.66	9.30	.70	......	......	......	......	......	6,266	11,279
				3	......	48.55	51.45	......	.77	......	......	......	......	......	6,908	12,434

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WYOMING—Continued.																
JOHNSON COUNTY—continued.																
Casper, 50 miles north of; prospect (3-foot 10-inch bed, 26-inch cut).	399	*11059	B	1	16.83	31.40	36.78	14.99	1.54	5.53	48.93	1.00	28.01	3.7	4,711	8,480
				2	....	37.76	44.22	18.02	1.85	4.40	58.83	1.20	15.70	....	5,664	10,195
				3	....	46.06	53.94	....	2.26	5.37	71.76	1.46	19.15	....	6,908	12,434
65 miles north of; sec. 20, T. 42 N., R. 77 W., Puggsley mine (20-foot 5-inch bed, 60-inch cut).	400	*10827	B	1	23.46	35.64	35.73	5.17	.49	6.50	51.24	.70	35.90	9.4	5,028	9,050
				2	....	46.56	46.69	6.75	.64	5.08	66.95	.91	19.67	....	6,569	11,824
				3	....	49.93	50.07	....	.69	5.45	71.79	.98	21.09	....	7,044	12,679
Kaycee, 6 miles northeast of; abandoned mine (exposed face in mine, entire section of bed).	400	10694	B	1	....	....	....	14.59	.56	....	....	....	....	10.4	4,431	7,976
				2	....	....	....	....	....	....	....	....	....	....	....	....
				3	....	....	....	....	....	....	....	....	....	....	....	....
NATRONA COUNTY.																
Casper, 25 miles southwest of; sec. 14, T. 31 N., R. 82 W., Red Ash mine (face of room 2, off main entry, 300 feet from entry mouth, 6-foot 3-inch bed).	400	*10671	B	1	29.50	27.48	37.66	5.36	.47	....	....	....	....	19.7	4,388	7,898
				2	....	38.98	53.42	7.60	.67	....	....	....	....	....	6,224	11,203
				3	....	42.19	57.81	....	.73	....	....	....	....	....	6,736	12,125
PARK COUNTY.																
Cody, 9 miles southeast of; NE. ¼ sec. 17, T. 52 N., R. 100 W.; McGuffey mine (east wall of room, 20 feet above entry 3 and 70 feet east of slope, 3-foot 1-inch bed, 2-foot 8-inch cut).	401	* 12886	B	1	15.52	35.95	40.51	8.02	.91	....	....	....	....	5.8	5,668	10,202
				2	....	42.55	47.96	9.49	1.08	....	....	....	....	....	6,710	12,078
				3	....	47.01	52.99	....	1.19	....	....	....	....	....	7,414	13,345
Meeteetse, 4 miles north of, and 32 miles southeast of Cody; sec. 21, T. 49 N., R. 100 W.; Black Diamond mine (face of room, 30 feet above entry 6 and 200 feet west of slope, 3-foot 6-inch bed and cut).	401	* 12887	B	1	17.80	30.89	43.50	7.81	.20	....	....	....	....	7.3	5,328	9,590
				2	....	37.58	52.92	9.50	.24	....	....	....	....	....	6,482	11,668
				3	....	41.53	58.47	....	.27	....	....	....	....	....	7,163	12,893
3½ miles southwest of, and 40 miles south of Cody; SE. ¼ sec. 13, T. 48 N., R. 101 W.; Greybull or Wilson mine; breast of room, 200 feet west of slope	401	* 12888	B	1	14.21	35.81	37.65	12.33	.92	....	....	....	....	5.5	5,335	9,603
				2	....	41.74	43.89	14.37	1.07	....	....	....	....	....	6,218	11,192
				3	....	48.74	51.26	....	1.25	....	....	....	....	....	7,261	13,070

and 400 feet from portal, 5-foot 7-inch bed, 4-foot 6-inch cut.																
Wiley, 13 miles southeast of Cody; SW. ¼ sec. 2, T. 51 N., R. 100 W.; Eagle mine (west wall of entry driven north from bottom of shaft, 6 feet from shaft, 5-foot 8-inch bed, 5-foot 5-inch cut).	402	* 12885	B	1	15.25	32.08	41.07	11.60	.53	....	....	....	....	6.8	5,264	9,475
				2	....	37.85	48.46	13.69	.63	....	....	....	....	....	6,211	11,180
				3	....	43.85	56.15	....	.73	....	....	....	....	....	7,196	12,953
14 miles southeast of Cody; SE. ¼ sec. 10, T. 51 N., R. 100 W.; East Wiley mine (south wall near bottom of slope, 180 feet from mine mouth, 4-foot bed, 3-foot 7-inch cut).	402	* 12884	B	1	15.82	35.40	41.01	7.77	.90	....	....	....	....	6.4	5,674	10,214
				2	....	42.05	48.72	9.23	1.07	....	....	....	....	....	6,740	12,132
				3	....	46.33	53.67	....	1.18	....	....	....	....	....	7,425	13,365
15 miles southeast of Cody; sec. 34, T. 51 N., R. 101 W.; West Wiley (Thompson) mine (face of room, off drift entry, 300 feet from entry mouth; 5-foot 7-inch bed, 3-foot 3-inch cut).	403	* 12883	B	1	14.80	35.16	38.46	11.58	.68	....	....	....	....	4.3	5,285	9,518
				2	....	41.27	45.14	13.59	.80	....	....	....	....	....	6,203	11,165
				3	....	47.76	52.24	....	.93	....	....	....	....	....	7,179	12,922
SHERIDAN COUNTY.																
Acme; sec. 13, T. 57 N., R. 85 W.; Acme No. 1 mine, Carney bed (8-foot cut).	403	* 12687	B	1	21.16	34.00	39.66	5.18	.35	6.01	54.87	1.11	32.48	8.0	5,211	9,380
				2	....	43.13	50.30	6.57	.44	4.64	69.60	1.41	17.34	....	6,610	11,898
				3	....	46.16	53.84	....	.47	4.97	74.49	1.51	18.56	....	7,075	12,735
Same (pillar of room 9, off east entry 5, off main entry, 6-foot 2-inch cut).	403	* 10823	A	1	22.48	33.19	39.75	4.58	.26	....	....	....	....	10.0	....	....
				2	....	42.82	51.27	5.91	.34	....	....	....	....	....	....	....
				3	....	45.51	54.49	....	.36	....	....	....	....	....	....	....
Same (pillar of room 1, off west entry 3, off main north entry, 6-foot 10-inch cut).	403	* 10824	A	1	22.84	31.93	40.64	4.59	.30	....	....	....	....	10.9	....	....
				2	....	41.38	52.67	5.95	.39	....	....	....	....	....	....	....
				3	....	44.00	56.00	....	.41	....	....	....	....	....	....	....
Same (composite of samples 10823 and 10824).....	403	* 10825	A	1	22.57	32.53	40.36	4.55	.30	6.30	53.43	1.09	34.33	10.5	5,121	9,218
				2	....	42.01	52.11	5.88	.39	4.89	69.00	1.41	18.43	....	6,614	11,905
				3	....	44.64	55.36	....	.41	5.20	73.31	1.50	19.58	....	7,027	12,649
Same (on pillar near face of west entry 3, off main north entry, 7-foot cut).	403	* 10826	A	1	22.08	33.43	40.11	4.38	.44	6.32	53.17	.96	34.73	9.4	5,142	9,256
				2	....	42.90	51.48	5.62	.56	4.97	68.24	1.23	19.38	....	6,599	11,878
				3	....	45.45	54.55	....	.59	5.27	72.30	1.30	20.54	....	6,992	12,586
Sec. 13, T. 57 N., R. 85 W.; Acme No. 2 mine; Carney and Masters bed (in mine 2,000 feet northwest of mine mouth, 8-foot 6-inch bed, 7-foot cut).	404	* 12683	B	1	23.88	34.11	38.20	3.81	.33	6.28	53.68	1.19	34.71	9.5	5,168	9,302
				2	....	44.81	50.18	5.01	.43	4.77	70.52	1.56	17.71	....	6,789	12,220
				3	....	47.17	52.83	....	.45	5.02	74.24	1.64	18.65	....	7,147	12,865
Same (face of room 13, off south entry 2, off west entry 3).	404	* 10807	A	1	23.04	33.39	39.99	3.58	.37	....	....	....	....	9.4	....	....
				2	....	43.39	51.96	4.65	.48	....	....	....	....	....	....	....
				3	....	45.51	54.49	....	.50	....	....	....	....	....	....	....
Same (face of south entry 5, off west entry 3).....	404	* 10808	A	1	22.21	32.63	41.66	3.50	.37	....	....	....	....	8.2	....	....
				2	....	41.95	53.55	4.50	.48	....	....	....	....	....	....	....
				3	....	43.93	56.07	....	.52	....	....	....	....	....	....	....
Same (face of room 1, off north entry 1, off west entry 5).	404	* 10809	A	1	23.14	32.48	41.33	3.05	.33	....	....	....	....	9.1	....	....
				2	....	42.27	53.76	3.97	.43	....	....	....	....	....	....	....
				3	....	44.02	55.98	....	.45	....	....	....	....	....	....	....
Same (composite of samples 10807, 10808, and 10809).	404	* 10810	A	1	22.72	32.17	41.74	3.37	.36	6.47	54.19	.99	34.62	8.9	5,191	9,344
				2	....	41.63	54.01	4.36	.47	5.11	70.12	1.28	18.66	....	6,717	12,091
				3	....	43.53	56.47	....	.49	5.34	73.32	1.34	19.51	....	7,023	12,641
Same (pillar of west entry 1).....................	404	* 10811	A	1	24.66	31.75	39.94	3.65	.38	6.48	52.31	1.20	35.98	11.3	5,004	9,007
				2	....	42.14	53.01	4.85	.50	4.96	69.43	1.59	18.67	....	6,642	11,956
				3	....	44.29	55.71	....	.53	5.21	72.97	1.67	19.62	....	6,981	12,566

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WYOMING—Continued.																
SHERIDAN COUNTY—continued.																
Carneyville, just north of; T. 57 N., R. 84 W.; Carney mine, Carney bed (in mine, 1,000 feet northwest of mine mouth, 16-foot bed, 10-foot cut).	405	* 12684	B	1	25.25	32.94	39.06	2.75	.32	6.28	53.49	1.11	36.05	11.6	5,089	9,160
				2	......	44.07	52.25	3.68	.43	4.64	71.56	1.48	18.21	......	6,808	12,254
				3	......	45.75	54.25	......	.45	4.82	74.29	1.54	18.90	......	7,068	12,722
½ mile from Alger; secs. 16 and 17, T. 57 N., R. 84 W.; Carney No. 1 mine, Carney bed (face of room 10, off north entry 4, off east entry 2, 10-foot 6-inch bed and cut).	405	* 15677	A	1	25.62	30.15	40.82	3.41	.36	......	......	......	......	14.7	5,035	9,063
				2	......	40.53	54.89	4.58	.48	......	......	......	......	......	6,769	12,184
				3	......	42.48	57.52	......	.50	......	......	......	......	......	7,094	12,769
Same (in room 9, off north entry 2, off west entry 4, 25 feet in from track, 11-foot 2-inch bed and cut).	405	* 15678	A	1	25.36	31.12	40.12	3.40	.40	......	......	......	......	14.8	5,080	9,144
				2	......	41.69	53.75	4.56	.54	......	......	......	......	......	6,806	12,251
				3	......	43.68	56.32	......	.57	......	......	......	......	......	7,131	12,836
Same (face of main entry, 10-foot 10-inch bed and cut).	405	* 15679	A	1	24.93	30.89	40.35	3.83	.40	......	......	......	......	14.0	5,052	9,094
				2	......	41.15	53.75	5.10	.53	......	......	......	......		6,730	12,114
				3	......	43.36	56.64	......	.56	......	......	......	......	......	7,091	12,764
Same (face of room 12, off north entry 4, off west entry 3, 75 feet from north entry 4, 10-foot 1-inch bed and cut).	405	* 15680	A	1	24.48	31.60	40.12	3.80	.41	......	......	......	......	13.2	5,116	9,209
				2	......	41.84	53.13	5.03	.54	......	......	......	......		6,775	12,195
				3	......	44.06	55.94	......	.57	......	......	......	......	......	7,134	12,841
⅓ mile from Alger; secs. 16 and 17, T. 57 N., R. 84 W.; Carney No. 2 mine, Carney bed (face of room 5, off north entry 2, off west entry 2, 11-foot 10-inch bed and cut).	405	* 15681	A	1	24.21	31.02	40.94	3.83	.53	......	......	......	......	13.0	5,147	9,265
				2	......	40.93	54.02	5.05	.70	......	......	......	......	......	6,791	12,224
				3	......	43.11	56.89	......	.74	......	......	......	......	......	7,152	12,874
Same (face of room 16, off north entry 3, off east entry 1, 85 feet from north entry 3, 11-foot 1-inch bed and cut).	405	* 15682	A	1	24.51	31.47	40.31	3.71	.40	......	......	......	......	13.2	5,143	9,257
				2	......	41.69	53.40	4.91	.53	......	......	......	......	......	6,813	12,263
				3	......	43.84	56.16	......	.56	......	......	......	......	......	7,165	12,897
Same (face of room 15, off north entry 2, off east entry 2, 125 feet in room, 10-foot 11-inch bed and cut).	405	*15683	A	1	24.20	30.91	41.42	3.47	.35	......	......	......	......	14.2	5,183	9,329
				2	......	40.78	54.64	4.58	.46	......	......	......	......	......	6,838	12,308
				3	......	42.74	57.26	......	.48	......	......	......	......	......	7,166	12,899
Same (face of main north entry, 11-foot 7-inch bed and cut).	405	*15684	A	1	24.61	31.31	39.87	4.21	.39	......	......	......	......	13.1	5,106	9,191
				2	......	41.53	52.89	5.58	.52	......	......	......	......	......	6,773	12,191
				3	......	43.98	56.02	......	.55	......	......	......	......	......	7,173	12,911

Same (face of room 9, off north entry 4, off west entry 1, 65 feet from north entry 4, 10-foot 5-inch bed and cut).	405	*15685	A	1	25.41	29.82	40.60	4.17	.36					16.0	5,032	9,058
				2		39.98	54.43	5.59	.48						6,746	12,143
				3		42.35	57.65		.51						7,145	12,861
Same (composite of samples 15677–15685; includes samples from No. 1 mine).	406	*15686	A	1	24.66	30.81	40.65	3.88	.37	6.26	53.23	1.07	35.19	14.0	5,101	9,182
				2		40.89	53.96	5.15	.49	4.67	70.65	1.42	17.62		6,771	12,188
				3		43.11	56.89		.52	4.92	74.49	1.50	18.57		7,139	12,850
Dietz; sec. 34, T. 57 N., R. 84 W.; Dietz No. 4 mine, Dietz No. 2 (?) bed (face of room 3, off west entry 4, 8-foot 5½-inch bed and cut).	406	*13498	A	1	23.87	30.31	37.60	8.22	1.23					14.9		
				2		39.81	49.39	10.80	1.62							
				3		44.63	55.37		1.82							
Same (face of room 1, off west entry 12, off main north entry, 7-foot 8-inch bed and cut).	406	*13499	A	1	21.79	31.24	39.46	7.51	.98					12.6		
				2		39.94	50.46	9.60	1.25							
				3		44.18	55.82		1.38							
Same (composite of samples 13498 and 13499).....	406	*13537	A	1	22.88	32.51	36.74	7.87	1.11	6.12	50.59	1.25	33.06	13.8	4,998	8,996
				2		42.16	47.63	10.21	1.44	4.64	65.60	1.62	16.49		6,481	11,666
				3		46.95	53.05		1.60	5.17	73.06	1.80	18.37		7,218	12,992
Same (face of room 9, off west entry 6, off north entry 6, 7-foot 4-inch bed and cut).	407	*16221	A	1	21.88	34.07	35.54	8.51	1.30					14.9	5,049	9,088
				2		43.61	45.50	10.89	1.66						6,463	11,633
				3		48.94	51.06		1.86						7,253	13,055
Same (face of room 2, off west entry 12, off north entry 4, 7-foot 7-inch bed and cut).	407	*16222	A	1	22.36	33.37	37.70	6.57	.95					14.4	5,131	9,236
				2		42.98	48.56	8.46	1.22						6,609	11,896
				3		46.95	53.05		1.33						7,220	12,996
Same (face of north entry 4, off west entry 4, 7-foot 3-inch bed and cut).	407	*16223	A	1	21.88	34.09	36.78	7.25	.95					14.5	5,136	9,245
				2		43.64	47.08	9.28	1.22						6,575	11,835
				3		48.10	51.90		1.34						7,248	13,046
Same (face of room 10, off east entry 5, off main north entry, 7-foot 5-inch bed and cut).	407	*16224	A	1	21.63	33.64	38.29	6.44	.92					13.9	5,200	9,360
				2		42.92	48.86	8.22	1.17						6,635	11,943
				3		46.77	53.23		1.27						7,229	13,012
Same (face of main north entry, 7-foot 1-inch bed and cut.)	407	*16225	A	1	23.56	32.32	38.17	5.95	.73					16.6	5,050	9,090
				2		42.28	49.94	7.78	.95						6,606	11,891
				3		45.85	54.15		1.03						7,164	12,895
Same (on pillar in room 9, off east entry 14, 8-foot 7-inch bed and cut).	407	*16226	A	1	23.38	32.75	37.77	6.10	.99					16.4	5,089	9,160
				2		42.74	49.30	7.96	1.29						6,642	11,956
				3		46.44	53.56		1.40						7,217	12,991
Same (face of main entry, 150 feet from mine mouth, 6-foot 1-inch bed and cut).	407	*16227	A	1	21.74	33.87	37.89	6.50	1.00					14.3	5,119	9,214
				2		43.28	48.41	8.31	1.28						6,541	11,774
				3		47.20	52.80		1.40						7,134	12,841
Same (composite of samples 16221–16227)	407	*16228	A	1	22.52	33.28	37.48	6.72	.97	6.32	52.33	1.21	32.45	15.0	5,100	9,180
				2		42.95	48.38	8.67	1.25	4.93	67.54	1.56	16.05		6,583	11,849
				3		47.03	52.97		1.37	5.40	73.95	1.71	17.57		7,208	12,974
Kool, 1½ miles south of; sec. 27, T. 57 N., R. 85 W.; Hughey prospect, Monarch (?) bed, 4-foot bed.	407	12642	B	1	24.64	35.17	35.31	4.88	.31					15.2	4,820	8,676
				2		46.67	46.85	6.48	.41						6,396	11,513
				3		49.90	50.10		.44						6,839	12,310
NW. ¼ sec. 23, T. 57 N., R. 85 W.; Kool mine; Carney(?) (Monarch) bed (in east entry, 2,100 feet from mine mouth, 23-foot bed, 9-foot cut).	408	*12641	B	1	22.39	35.05	37.50	5.06	.55					11.9	5,104	9,187
				2		45.16	48.32	6.52	.71						6,577	11,839
				3		48.31	51.69		.76						7,035	12,663
Same (face of room 20, off fifth east entry, first panel, 7-foot 11-inch cut).	408	*16060	A	1	23.96	32.72	37.94	5.38	.65					17.0	5,065	9,117
				2		43.03	49.89	7.08	.85						6,661	11,990
				3		46.31	53.69		.91						7,169	12,904
Same (face of room 9, off fifth east entry, fourth panel, 9-foot cut).	408	*16061	A	1	24.02	33.12	38.40	4.46	.54					9.0	5,099	9,178
				2		43.59	50.54	5.87	.71						6,711	12,080
				3		46.31	53.69		.75						7,130	12,834

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WYOMING—Continued.																
SHERIDAN COUNTY—continued.																
Kool, NW. ¼ sec. 23, T. 57 N., R. 85 W.; Kool mine; Carney (?) (Monarch) bed (face of fifth east entry, 1,900 feet from the main slope, 7-foot 11-inch cut).	408	*16062	A	1	23.07	33.50	38.78	4.65	.60					11.9	5,182	9,328
				2		43.55	50.41	6.04	.78						6,736	12,125
				3		46.35	53.65		.83						7,169	12,904
Same (last crosscut off fourteenth east entry; 165 feet from main slope; 7-foot 9-inch cut).	408	*16063	A	1	23.02	33.76	38.88	4.34	.64					7.2	5,192	9,346
				2		43.85	50.51	5.64	.83						6,744	12,139
				3		46.47	53.53		.88						7,147	12,865
Same (face of room 4, off tenth east entry, fourth panel, 8-foot 6-inch cut).	408	*16064	A	1	23.66	32.49	39.62	4.23	.48					10.0	5,099	9,178
				2		42.56	51.90	5.54	.63						6,679	12,022
				3		45.05	54.95		.67						7,070	12,726
Same (face of room 7, off tenth east entry, second panel, 8-foot 4-inch cut).	408	*16065	A	1	22.14	34.29	37.82	5.75	1.00					8.4	5,133	9,239
				2		44.04	48.57	7.39	1.28						6,593	11,867
				3		47.55	52.45		1.38						7,119	12,814
Same (face of twelfth west entry; 185 feet from main slope; 8-foot 2-inch cut).	408	*16066	A	1	23.64	32.98	38.64	4.74	.66					8.9	5,084	9,151
				2		43.19	50.60	6.21	.86						6,658	11,984
				3		46.05	53.95		.92						7,099	12,778
Same (composite of samples 16060-16066)	408	*16067	A	1	23.35	33.86	38.08	4.71	.64	6.30	53.10	1.25	34.00	10.3	5,116	9,209
				2		44.17	49.69	6.14	.83	4.84	69.27	1.63	17.29		6,674	12,013
				3		47.06	52.94		.88	5.16	73.80	1.74	18.42		7,110	12,798
Same (face of room 9, off fifth west entry, off main entry, 8-foot 5-inch cut).	408	*10818	A	1	23.60	32.12	39.19	5.09	.57					10.8		
				2		42.04	51.30	6.66	.75							
				3		45.04	54.96		.80							
Same (face of main air course, which is also a manway, 8-foot 6-inch cut).	408	*10819	A	1	24.60	30.63	39.99	4.78	.53					12.4		
				2		40.62	53.04	6.34	.70							
				3		43.37	56.63		.75							
Same (face of room 3, off seventh west entry, 8-foot 9½-inch cut).	408	*10820	A	1	23.84	31.99	39.16	5.01	.48					11.4		
				2		42.00	51.42	6.58	.63							
				3		44.96	55.04		.67							
Same (face of room 6, off fifth east entry, off main entry, 8-foot ½-inch cut).	408	*10821	A	1	22.71	32.27	39.96	5.06	.59					9.6		
				2		41.75	51.70	6.55	.76							
				3		44.68	55.32		.81							
Same (composite of samples 10818-10821)	409	*10822	A	1	23.49	31.22	40.40	4.89	.50	6.57	52.00	.96	35.08	11.1	5,067	9,121
				2		40.80	52.81	6.39	.65	5.18	67.96	1.25	18.57		6,623	11,921
				3		43.59	56.41		.69	5.53	72.60	1.34	19.84		7,075	12,785

Monarch; Monarch mine, Monarch bed (pillar of butt entry 3, off west entry 9, near room 70, 7-foot 10-inch cut).	409	12005	A	1	22.25	35.01	39.01	3.73	.37	6.27	55.28	1.07	33.28	11.1	5,343	9,617
				2	....	45.03	50.17	4.80	.48	4.89	71.10	1.38	17.35	....	6,872	12,370
				3	....	47.30	52.70	....	.50	5.14	74.68	1.45	18.23	....	7,218	12,992
Same (pillar of west entry 9, near room 70, 8-foot 2-inch cut).	409	*12008	A	1	23.05	31.89	41.83	3.23	.37	6.44	54.65	1.10	34.21	9.5	5,269	9,484
				2	....	41.44	54.36	4.20	.48	5.04	71.02	1.43	17.83	....	6,847	12,325
				3	....	43.26	56.74	....	.50	5.26	74.13	1.49	18.62	....	7,147	12,865
Same (face of room 70, near west entry 7, 8-foot 2-inch cut).	409	*12006	A	1	23.41	33.55	39.44	3.60	.39	6.42	54.38	1.03	34.18	10.0	5.218	9,392
				2	....	43.81	51.49	4.70	.51	4.99	71.00	1.34	17.46	....	6,813	12,263
				3	....	45.97	54.03	....	.54	5.24	74.50	1.41	18.31	....	7,149	12,868
West of; SE. ¼ sec. 24, T. 57 N., R. 85 W.; New Monarch mine, Monarch bed (800 feet southwest of mine mouth, 10-foot cut).	409	*12685	B	1	23.88	34.33	38.44	3.35	.38	6.29	54.07	1.14	34.77	8.1	5,186	9,335
				2	....	45.10	50.50	4.40	.50	4.78	71.03	1.50	17.79	....	6,813	12,263
				3	....	47.17	52.83	....	.52	5.00	74.30	1.57	18.61	....	7,126	12,827
Same (face of east entry 6, 250 feet from main haulage slope, 9-foot 2-inch cut).	409	*15830	A	1	24.67	32.48	39.40	3.45	.44	....	....	....	....	15.9	5,139	9,250
				2	....	43.12	52.30	4.58	.58	....	....	....	....	....	6,822	12,280
				3	....	45.19	54.81	....	.61	....	....	....	....	....	7,149	12,868
Same (face of west entry 8, 9-foot 4-inch cut).....	409	*15831	A	1	22.56	34.36	38.74	4.34	.58	....	....	....	....	14.0	5,214	9,385
				2	....	44.37	50.03	5.60	.75	....	....	....	....	....	6,733	12,119
				3	....	47.00	53.00	....	.79	....	....	....	....	....	7,132	12,838
Same (face of west entry 13, off old slope, 8-foot 11-inch cut).	410	*15832	A	1	22.78	33.21	40.64	3.37	.32	....	....	....	....	13.6	5,282	9,508
				2	....	43.01	52.63	4.36	.41	....	....	....	....	....	6,840	12,312
				3	....	44.97	55.03	....	.43	....	....	....	....	....	7,152	12,874
Same (in west entry 4, opposite fifth and sixth butts, 800 feet from haulage way, 10 foot 1-inch cut).	410	*15833	A	1	22.26	34.79	38.81	4.14	.44	....	....	....	....	12.8	5,285	9,513
				2	....	44.75	49.92	5.33	.57	....	....	....	....	....	6,798	12,236
				3	....	47.27	52.73	....	.60	....	....	....	....	....	7,181	12,926
Same (face of room 8, off butt entry 4, off west entry 4, 10-foot 4-inch cut).	410	*15834	A	1	24.31	32.99	38.76	3.94	.49	....	....	....	....	14.3	5,143	9,257
				2	....	43.59	51.20	5.21	.65	....	....	....	....	....	6,795	12,231
				3	....	45.99	54.01	....	.69	....	....	....	....	....	7,169	12,904
Same (pillar between rooms 24 and 25, off west entry 12, 9-foot cut).	410	*15835	A	1	22.46	34.16	39.54	3.84	.49	....	....	....	....	12.8	5,280	9,504
				2	....	44.06	50.99	4.95	.63	....	....	....	....	....	6,810	12,258
				3	....	46.36	53.64	....	.66	....	....	....	....	....	7,165	12,897
Same (pillar between rooms 5 and 6, off butt entry 2, off west entry 3, 9-foot 9-inch cut).	410	*15836	A	1	22.42	34.17	39.58	3.83	.49	....	....	....	....	12.6	5,296	9,533
				2	....	44.05	51.01	4.94	.63	....	....	....	....	....	6,827	12,289
				3	....	46.34	53.66	....	.66	....	....	....	....	....	7,182	12,928
Same (composite of samples 15830–15836).........	410	*15837	A	1	23.24	33.01	39.88	3.87	.46	6.29	54.33	1.09	33.96	13.7	5,219	9,394
				2	....	43.01	51.95	5.04	.60	4.83	70.78	1.42	17.33	....	6,799	12,238
				3	....	45.29	54.71	....	.63	5.09	74.54	1.50	18.24	....	7,160	12,888
New Acme; sec. 22, T. 57 N., R. 84 W.; New Acme mine, Monarch bed (face of west entry 7, 150 feet from main slope, 6-foot 8-inch cut).	410	*16055	A	1	23.66	31.75	41.66	2.93	.41	....	....	....	....	9.3	5,257	9,463
				2	....	41.59	54.57	3.84	.54	....	....	....	....	....	6,886	12,395
				3	....	43.25	56.75	....	.56	....	....	....	....	....	7,161	12,890
Same (face of room 4, off east entry 5, 7-foot 2-inch cut).	410	*16056	A	1	21.71	33.51	40.80	3.98	.63	....	....	....	....	7.1	5,407	9,733
				2	....	42.80	52.12	5.08	.80	....	....	....	....	....	6,906	12,431
				3	....	45.09	54.91	....	.84	....	....	....	....	....	7,275	13,095
Same (face of room 13, off east entry 3, 7-foot 7-inch cut).	410	*16057	A	1	24.29	33.49	38.68	3.54	.58	....	....	....	....	10.3	5,244	9,439
				2	....	44.23	51.09	4.68	.77	....	....	....	....	....	6,926	12,467
				3	....	46.40	53.60	....	.81	....	....	....	....	....	7,266	13,079
Same (face of room 11, off east entry 2, 6-foot 9-inch cut).	410	*16058	A	1	24.24	31.44	41.55	2.77	.43	....	....	....	....	10.1	5,218	9,392
				2	....	41.50	54.84	3.66	.57	....	....	....	....	....	6,888	12,398
				3	....	43.08	56.92	....	.59	....	....	....	....	....	7,150	12,870
Same (composite of samples 16055–16058).........	410	*16059	A	1	23.30	32.05	41.34	3.31	.53	6.35	54.96	1.01	33.84	9.2	5,296	9,533
				2	....	41.79	53.89	4.32	.69	4.90	71.66	1.32	17.11	....	6,905	12,429
				3	....	43.67	56.33	....	.72	5.12	74.89	1.38	17.89	....	7,216	12,989

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WYOMING—Continued.																
SWEETWATER COUNTY.																
Gunn, 4 miles from Baxter Junction; sec. 8, T. 19 N., R. 104 W.; B mine, No. 11 bed (face of room 15, off entry 5, 6-foot 2-inch bed).	411	11507	A	1	17.37	33.89	46.76	1.98	.92	......	......	......	......	13.3	......	......
				2	......	41.01	56.59	2.40	1.11	......	......	......	......	......	......	......
				3	......	42.02	57.98	......	1.14	......	......	......	......	......	......	......
Same (face of room 25, off entry 4, 6-foot 1-inch bed).	411	11508	A	1	15.79	33.96	48.27	1.98	.79	......	......	......	......	11.5	......	......
				2	......	40.33	57.32	2.35	.94	......	......	......	......	......	......	......
				3	......	41.30	58.70	......	.96	......	......	......	......	......	......	......
Same (face of room 8, off entry 8, 6-foot 2-inch bed).	411	11509	A	1	16.03	34.65	47.16	2.16	.95	......	......	......	......	11.8	......	......
				2	......	41.26	56.17	2.57	1.13	......	......	......	......	......	......	......
				3	......	42.35	57.65	......	1.16	......	......	......	......	......	......	......
Same (composite of samples 11507, 11508, 11509)..	411	11510	A	1	16.32	34.86	46.77	2.05	.87	6.15	63.61	1.33	25.99	12.2	6,196	11,153
				2	......	41.66	55.89	2.45	1.04	5.19	76.01	1.59	13.72	......	7,404	13,327
				3	......	42.71	57.29	......	1.07	5.32	77.92	1.63	14.06	......	7,590	13,662
Superior; sec. 29, T. 21 N., R. 102 W.; B mine, No. 7 bed (room 27, off inside dip entry, 7-foot 2-inch bed and cut).	412	11461	A	1	11.07	37.49	47.93	3.51	1.03	......	......	......	......	7.4	......	......
				2	......	42.16	53.89	3.95	1.16	......	......	......	......	......	......	......
				3	......	43.89	56.11	......	1.21	......	......	......	......	......	......	......
Same (face of south entry 2, 7-foot 4¾-inch bed and cut).	412	11462	A	1	12.65	36.61	47.29	3.45	1.01	......	......	......	......	8.6	......	......
				2	......	41.91	54.14	3.95	1.16	......	......	......	......	......	......	......
				3	......	43.63	56.37	......	1.21	......	......	......	......	......	......	......
Same (face of room 20, off south entry 3, 7-foot 3¾-inch bed and cut).	412	11463	A	1	11.74	37.15	47.52	3.59	.80	......	......	......	......	7.1	......	......
				2	......	42.09	53.84	4.07	.91	......	......	......	......	......	......	......
				3	......	43.87	56.13	......	.95	......	......	......	......	......	......	......
Same (room 11, off north entry 3, 6-foot 3½-inch bed and cut).	412	11464	A	1	11.64	37.86	47.24	3.26	.86	......	......	......	......	7.0	......	......
				2	......	42.85	53.46	3.69	.97	......	......	......	......	......	......	......
				3	......	44.49	55.51	......	1.01	......	......	......	......	......	......	......
Same (composite of samples 11461–11464).........	412	11465	A	1	11.79	36.96	47.88	3.37	.99	5.90	67.87	1.44	20.43	7.5	6,666	11,999
				2	......	41.90	54.28	3.82	1.12	5.20	76.94	1.63	11.29	......	7,557	13,603
				3	......	43.56	56.44	......	1.16	5.41	79.99	1.69	11.75	......	7,857	14,143
Sec. 21, T. 21 N., R. 101 W., Superior C mine, No. 1 bed (room 15, off south entry 6, 8-foot 7½-inch bed, 8-foot 6-inch cut).	412	11456	A	1	12.53	36.22	47.36	3.89	1.05	......	......	......	......	9.0	......	......
				2	......	41.41	54.14	4.45	1.20	......	......	......	......	......	......	......
				3	......	43.34	56.66	......	1.26	......	......	......	......	......	......	......

Same (room 25, off south entry 5, 8-foot 7½-inch bed, 8-foot 6-inch cut).	412	11457	A	1	13.26	36.54	48.33	1.87	1.00	......	......	......	......	9.7	......	......
				2	......	42.13	55.71	2.16	1.15	......	......	......	......	......	......	......
				3	......	43.06	56.94	......	1.18	......	......	......	......	......	......	......
Same (room 1, off north entry 7, 6-foot 7-inch bed and cut).	412	11458	A	1	13.34	36.07	47.70	2.89	.83	......	......	......	......	9.5	......	......
				2	......	41.62	55.05	3.33	.96	......	......	......	......	......	......	......
				3	......	43.05	56.95	......	.99	......	......	......	......	......	......	......
Same (room 38, south entry 4, 8-foot 6½-inch bed, 8-foot 5-inch cut).	412	11459	A	1	13.79	35.15	46.68	4.38	1.00	......	......	......	......	10.1	......	......
				2	......	40.77	54.15	5.08	1.16	......	......	......	......	......	......	......
				3	......	42.95	57.05	......	1.22	......	......	......	......	......	......	......
Same (composite of samples 11456, 11457, 11458, and 11459).	412	11460	A	1	13.11	35.75	47.74	3.40	1.00	5.87	66.17	1.25	22.31	9.6	6,455	11,619
				2	......	41.14	54.95	3.91	1.15	5.08	76.16	1.44	12.26	......	7,429	13,372
				3	......	42.81	57.19	......	1.20	5.29	79.26	1.50	12.75	......	7,731	13,916
UINTA COUNTY.																
Elkol; sec. 11, T. 20 N., R. 117 W.; Elkol mine, No. 1 bed (face of north entry 3, 1,900 feet from slope mouth, 51-foot bed, 8-foot 6-inch cut).	413	11730	A	1	21.45	35.29	40.42	2.84	.61	6.40	58.35	.77	31.03	15.2	5,698	10,256
				2	......	44.93	51.45	3.62	.78	5.12	74.29	.98	15.21	......	7,254	13,057
				3	......	46.62	53.38	......	.81	5.31	77.08	1.02	15.78	......	7,527	13,549
Same (face of room 1, off north entry 3, 1,450 feet from slope mouth, 51-foot bed, 8-foot 6-inch cut).	413	11731	A	1	20.60	35.09	39.86	4.45	.57	6.28	57.32	.78	30.60	14.9	5,610	10,098
				2	......	44.19	50.21	5.60	.72	5.03	72.19	.98	15.48	......	7,065	12,717
				3	......	46.81	53.19	......	.76	5.33	76.47	1.04	16.40	......	7,484	13,471
Frontier; sec. 12, T. 21 N., R. 116 W.; Kemmerer No. 1 mine, No. 1 bed (face of room 16, off south entry 13, 8-foot 4-inch cut).	413	11565	A	1	5.65	37.70	51.34	5.31	1.41	5.46	70.58	1.02	16.22	2.9	6,989	12,580
				2	......	39.96	54.41	5.63	1.49	5.12	74.81	1.08	11.87	......	7,408	13,334
				3	......	42.35	57.65	......	1.58	5.43	79.28	1.14	12.57	......	7,850	14,130
Same (pillar of room 18, off north entry 10, 8-foot 5-inch bed, 8-foot 1-inch cut).	413	11566	A	1	6.29	39.04	51.14	3.53	.90	5.54	71.95	.98	17.10	3.5	7,100	12,780
				2	......	41.66	54.57	3.77	.96	5.16	76.78	1.05	12.28	......	7,576	13,637
				3	......	43.29	56.71	......	1.00	5.36	79.79	1.09	12.76	......	7,873	14,171
Same (face of room 3, off north entry 7, 5-foot 10-inch bed, 5-foot 4-inch cut).	413	11567	A	1	5.57	37.44	47.46	9.53	1.40	5.50	67.43	.93	15.21	3.0	6,669	12,004
				2	......	39.65	50.26	10.09	1.48	5.17	71.41	.98	10.87	......	7,062	12,712
				3	......	44.10	55.90	......	1.65	5.75	79.42	1.09	12.09	......	7,854	14,137
Same (stub pillar of room 62, off south entry 7, 6-foot bed, 5-foot 2-inch cut).	413	11568	A	1	5.18	38.73	47.54	8.55	1.40	5.53	68.08	1.10	15.34	2.7	6,783	12,209
				2	......	40.84	50.14	9.02	1.48	5.22	71.80	1.16	11.32	......	7,153	12,875
				3	......	44.89	55.11	......	1.63	5.74	78.92	1.27	12.44	......	7,862	14,152
Kemmerer, 1½ miles west of; sec. 33, T. 22 N., R. 116 W.; prospect (face of first entry, 200 feet from mouth of slope, 16-foot bed).	414	11740	A	1	18.07	37.09	42.34	2.50	1.95	6.27	60.01	1.05	28.22	9.6	5,905	10,629
				2	......	45.27	51.68	3.05	2.38	5.20	73.25	1.28	14.84	......	7,208	12,974
				3	......	46.70	53.30	......	2.45	5.36	75.56	1.32	15.31	......	7,435	13,383
Susie, 4 miles north of Kemmerer; secs. 25 and 26, T. 22 N., R. 116 W.; Kemmerer No. 4 mine, Kemmerer No. 1 bed (in mine, 1,000 feet from mouth of slope, 5-foot 2 inch bed and cut).	414	13517	A	1	6.19	39.63	48.42	5.76	1.31	......	......	......	......	3.0	......	......
				2	......	42.25	51.61	6.14	1.40	......	......	......	......	......	......	......
				3	......	45.01	54.99	......	1.49	......	......	......	......	......	......	......
Same (face of north entry 2, 1,300 feet from mouth of slope, 4-foot 3-inch bed and cut).	414	13518	A	1	7.00	38.93	47.09	6.98	1.34	......	......	......	......	3.8	......	......
				2	......	41.86	50.63	7.51	1.44	......	......	......	......	......	......	......
				3	......	45.26	54.74	......	1.56	......	......	......	......	......	......	......
Same (composite of samples 13517 and 13518).....	414	13519	A	1	6.56	39.20	47.78	6.46	1.37	5.29	69.56	1.25	16.07	3.4	6,866	12,359
				2	......	41.95	51.14	6.91	1.47	4.88	74.44	1.34	10.96	......	7,348	13,226
				3	......	45.06	54.94	......	1.58	5.24	79.96	1.44	11.78	......	7,893	14,207

Table of chemical analyses—Continued.

Locality, bed, etc.	Mine notes (page).	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
		Laboratory No.	Kind.	Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WYOMING—Continued.																
WESTON COUNTY.																
Cambria, 6¼ miles from Newcastle; sec. 20, T. 46 N., R. 61 W.; Antelope No. 4 mine (face of east entry 1, 3-foot 11-inch bed, 2-foot 11-inch cut).	415	16,412	A	1	10.97	38.25	33.30	17.48	4.80	....	....	....	....	8.5	5,508	9,914
				2	....	42.96	37.41	19.63	5.39	....	....	....	....	....	6,187	11,137
				3	....	53.45	46.55	....	6.71	....	....	....	....	....	7,698	13,856
Same (face of north entry 1, off east entry 1; 6-foot 1-inch bed, 5-foot 3-inch cut).	415	16413	A	1	10.35	39.75	34.65	15.25	4.99	....	....	....	....	7.6	5,725	10,305
				2	....	44.34	38.65	17.01	5.57	....	....	....	....	....	6,386	11,495
				3	....	53.43	46.57	....	6.71	....	....	....	....	....	7,695	13,851
Same (face of room 29 off east entry 3, 8-foot 11-inch bed, 6-foot 2-inch cut).	415	16414	A	1	10.84	38.99	37.78	12.44	5.07	....	....	....	....	8.2	5,969	10,744
				2	....	43.73	42.32	13.95	5.69	....	....	....	....	....	6,695	12,051
				3	....	50.82	49.18	....	6.66	....	....	....	....	....	7,780	14,004
Same (composite of samples 16412, 16413, and 16414).	415	16415	A	1	10.77	39.10	35.10	15.08	4.87	5.46	56.09	.74	17.81	8.1	5,745	10,341
				2	....	43.82	39.34	16.84	5.46	4.77	62.86	.83	9.24	....	6,438	11,588
				3	....	52.69	47.31	....	6.57	5.74	75.59	1.00	11.10	....	7,742	13,936
Sec. 19, T. 46 N., R. 61 W.; Antelope No. 3 mine (face of room 35, off east entry 5; 3-foot 9-inch bed and cut).	415	16428	A	1	11.88	37.32	34.64	16.16	4.67	....	....	....	....	9.2	5,578	10,031
				2	....	42.35	39.31	18.34	5.30	....	....	....	....	....	6,324	11,383
				3	....	51.86	48.14	....	6.49	....	....	....	....	....	7,744	13,939
Same (face of west entry 8, 7-foot 3-inch bed, 6-foot 6-inch cut).	415	16429	A	1	9.52	40.79	34.24	15.45	4.98	....	....	....	....	7.2	5,837	10,507
				2	....	45.08	37.84	17.08	5.50	....	....	....	....	....	6,451	11,612
				3	....	54.37	45.63	....	6.63	....	....	....	....	....	7,780	14,004
Same (face of west entry 7, 7-foot 5-inch bed, 6-foot 11-inch cut).	415	16430	A	1	8.92	38.41	34.71	17.96	4.92	....	....	....	....	6.2	5,676	10,217
				2	....	42.17	38.11	19.72	5.40	....	....	....	....	....	6,232	11,218
				3	....	52.53	47.47	....	6.73	....	....	....	....	....	7,763	13,973
Same (composite of samples 16428, 16429, and 16430).	415	16431	A	1	10.00	39.11	34.33	16.56	4.90	5.36	55.21	.68	17.29	7.5	5,693	10,247
				2	....	43.46	38.14	18.40	5.44	4.72	61.34	.76	9.34	....	6,325	11,385
				3	....	53.26	46.74	....	6.67	5.78	75.17	.93	11.45	....	7,751	13,952
Moorcroft, 12 miles south of, 15 miles northwest of Upton; SE. ¼ sec. 29, T. 48 N., R. 67 W.; prospect (face of entry, 100 feet north of mine mouth; 3-foot bed, 2-foot 11-inch cut).	416	*12446	B	1	26.08	31.05	36.86	6.01	.56	6.26	49.36	.91	36.90	14.0	4,647	8,365
				2	....	42.00	49.87	8.13	.76	4.55	66.77	1.23	18.56	....	6,286	11,315
				3	....	45.72	54.28	....	.83	4.95	72.68	1.34	20.20	....	6,842	12,316
12 miles southwest of; sec. 29, T. 48 N., R. 68 W.; prospect (28-inch bed and cut).	416	*12392	B	1	29.97	28.77	34.52	6.74	.92	....	....	....	....	17.2	4,279	7,702
				2	....	41.08	49.30	9.62	1.31	....	....	....	....	....	6,110	10,998
				3	....	45.45	54.55	....	1.45	....	....	....	....	....	6,760	12,168

DESCRIPTIONS OF SAMPLES.

ALABAMA.

JEFFERSON COUNTY.

LITTLETON. BANNER MINE.

Sample.—Bituminous coal; Warrior field; analyses Nos. 12083, 12084, 12085, and 12086 (p. 17).

Mine.—Banner, a shaft (originally a slope) mine near Littleton, about 20 miles northwest of Birmingham, on the Cane Creek division of the Louisville & Nashville Railroad.

Coal bed.—Big or Mary Lee. Carboniferous age, Pottsville group. This same bed is worked at Palos, Ala. Thickness about 10 feet. The bed is practically horizontal, the dip being 1 to 2 per cent. The bed is overlain by sandstone and the floor is shale. Near the center of the bed is a stratum of hard gray shale 18 to 22 inches thick, known as "middleman." The bed was measured and sampled at three points in the mine by J. J. Rutledge, on April 26, 1911, as described below:

Sections of coal bed in Banner mine.

Section	A		B		C	
Laboratory No.	12083		12084		12085	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	2	1	4	1	2
Shale, gray	[a]0	1	[a]0	1	[a]0	1
Coal	0	8	0	8	0	7
Shale, hard, gray	..	..	[a]0	8	[a]0	10
Coal	1	8	1	4	1	9
"Sulphur"	..	..	[a]0	1	..	..
Coal	..	..	0	4	..	..
"Sulphur" ("slate")	[a]0	1	[a]0	1	[a]0	1
Coal	0	6	0	6	0	6
Shale, hard, gray	[a]1	6	[a]1	9	[a]1	9
Coal	2	8	2	7	2	7
Shale, gray	0	1	[a]0	2	0	1
Coal	0	7½	0	9	0	7
Floor, shale.						
Thickness of bed	8	7½	10	4	10	0
Thickness of coal sampled	6	11½	7	6	7	4

[a] Not included in sample.

Section A (sample 12083) was cut from the rib near the mouth of room 4, off right entry 5, 2,000 feet east of shaft No. 1.

Section B (sample 12084) was cut from the rib near the mouth of room 2, off left entry 8, 2,400 feet east of shaft No. 1.

Section C (sample 12085) was cut from the right rib of the main slope, at the mouth of left entry 9, 2,700 feet east of shaft No. 1.

A composite sample was made by combining face samples 12083, 12084, and 12085. The results of an ultimate analysis of this sample are given under Laboratory No. 12086.

Notes.—The room-and-pillar system of mining is used. At the time of sampling the coal was undercut by electric chain machines and shot down with a permissible explosive. The output was about 1,000 tons a day, all of which was from advance workings. In advance workings, about 40 per cent of the coal was taken out.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 285, 1906, p. 216.

MORRIS. INDIO MINE.

Sample.—Bituminous coal; Warrior field; analyses Nos. 16683, 16684, 16685, 16686, and 16687 (p. 17).

Mine.—The Indio mine is opened by a shaft 186 feet deep, and is 4 miles east of Morris, on the Louisville & Nashville Railroad.

Coal bed.—Jefferson. Carboniferous age, Black Creek formation. Thickness, 4 feet to 4 feet 8 inches. The bed lies practically horizontal and has two characteristic shale partings, one near the bottom and one near the top. Roof, shale, with a sandstone cap rock. The shale occasionally came down with the coal and particles of the roof got mixed with the coal in loading. The floor is a hard, smooth shale, particles of which did not get mixed with the coal in mining.

The bed was measured and sampled at four points in the mine by E. B. Sutton and J. W. Webb, on March 28, 1913, as described below:

Sections of coal bed in Indio mine.

Sections	A		B		C		D	
Laboratory No.	16683		16684		16685		16686	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, shale.								
Coal	0	7	0	8	0	8½	0	8½
Shale	[a]0	2	[a]0	3	[a]0	5	[a]0	3½
Coal	1	6	1	7	1	2	1	3½
Shale	[a]1	8	[a]1	8	[a]1	8	[a]1	2½
Coal	0	6	0	6	0	6	0	7
Floor, shale.								
Thickness of bed	4	5	4	8	4	½	4	1
Thickness of coal sampled	2	7	2	9	2	4½	2	7

[a] Not included in sample.

Section A (sample 16683) was measured at the face of room 7, off the fifth left south entry.

Section B (sample 16684) was measured at the face of room 4, off the seventh right north entry.

Section C (sample 16685) was measured at the neck of room 4, off the sixth right south entry.

Section D (sample 16686) was measured at the intersection of the main south air course and the sixth left south entry.

A composite sample was made by combining face samples 16683 to 16686, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 16687.

Notes.—At the time the mine was visited the coal was shot off the solid with permissible explosives. Black powder was used for brushing the floor and roof. The coal was all shipped as run-of-mine. The average daily output was 275 tons. There was about 100 acres to be mined from this opening.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 285, 1906, p. 219.

ST. CLAIR COUNTY.

COAL CITY. COAL BRANCH MINE.

Sample.—Bituminous coal; Coosa Basin field; analyses Nos. 12440, 12441, 12442, and 12443 (p. 18).

Mine.—Coal Branch, a slope mine at Coal City, on the Seaboard Air Line Railway.

Coal bed.—Coal City. Carboniferous age, Pottsville group. Thickness, 2 feet 10 inches to 5 feet; roof, weak calcareous shale; floor, hard shale.

The bed was measured and sampled at three points in the mine by Charles Butts on July 21, 1911, as described below:

Section of coal bed in Coal Branch mine.

Section	A		B		C	
Laboratory No	12440		12441		12442	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	4	10	3	10	2	10
"Rash"	[a]0	2				
Floor, shale, hard.						
Thickness of bed	5	0	3	10	2	10
Thickness of coal sampled	4	10	3	10	2	10

[a] Not included in sample.

Section A (sample 12440) was measured in the first left room off twenty-sixth entry, 3,000 feet north of the slope mouth.

Section B (sample 12441) was measured at the end of thirty-fourth entry, 2,800 feet north of the slope mouth.

Section C (sample 12442) was measured at the end of room 32, 3,000 feet northeast of the slope mouth.

A composite sample was made by combining face samples 12440, 12441, and 12442. The results of an ultimate analysis of this sample are shown under laboratory No. 12443.

COAL CITY. VULCAN NO. 4 MINE.

Sample.—Bituminous coal; Coosa Basin field; analyses Nos. 12436, 12437, 12438, 12439 (p. 18).

Mine.—Vulcan No. 4; a slope mine at Coal City, on the Seaboard Air Line Railway.

Coal bed.—Broken Arrow. Carboniferous age, Pottsville group. Thickness, 3 feet 6 inches to 4 feet 9 inches.

The bed was measured and sampled at three points in the mine by Charles Butts on July 21, 1911, as described below:

Section of coal bed in Vulcan No. 4 mine.

Section	A		B		C	
Laboratory No	12436		12437		12438	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, bony	[a]0	8	[a]0	5	[a]0	4
Clay	[a]0	3½	[a]0	5	[a]0	3½
Coal, bony	[a]0	3½	[a]0	3	[a]0	3
Coal, hard	1	..	0	10	0	9
Coal, soft	1	6	1	10	1	10
Coal, rashy, "mining"	0	9½	1	0	0	10
Floor, shale.						
Thickness of bed	4	1½	4	9	4	3½
Thickness of coal sampled	3	3½	3	8	3	5

[a] Not included in sample.

Section A (sample 12436) was measured in room 21, off second left heading, 750 feet southeast of the mine mouth.

Section B (sample 12437) was measured 1,100 feet east of the mine mouth.

Section C (sample 12438) was measured in room 15, off second left heading, 600 feet south of the mine mouth.

A composite sample was made by combining face samples 12436, 12437, and 12438. The results of an ultimate analysis of this sample are shown under laboratory No. 12439.

SHELBY COUNTY.

STRAVEN. STRAVEN MINE.

Sample.—Bituminous coal; Cahaba field; analyses Nos. 14391 and 14392 (p. 18).

Mine.—Straven, a slope mine in sec. 7, T. 21S., R. 3 W., at Straven, on the Mobile branch of the Southern Railway.

Coal bed.—Upper Straven. Carboniferous age, Pottsville group. Thickness, 5 feet 6½ inches.

The bed was measured and sampled at one point in the mine by Charles Butts on June 14, 1912, as described below:

Section of coal bed in Straven mine.

Laboratory No	14391 14392	
Roof, shale.	*Ft.*	*in.*
Coal, rash, and shale	[a] 0	8
Coal, hard	[b] 0	10½
Parting (knife edge to 4 inches of rash or soft coal)		
Coal	[b] 2	2
Clay	[a] 0	8½
Coal, softer than upper bench	[c] 1	1½
Floor, clay:		
Thickness of bed	4	4½

[a] Excluded from samples. [b] Included in sample 14391. [c] Included in sample 14392.

The section was measured near the end of the slope, 2,000 feet north of the slope mouth.

Notes.—The coal was hard and bright. At the time of sampling, the coal was sold as run-of-mine for domestic and steam purposes.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 39, 351.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 431, 1909, p. 140.

TUSCALOOSA COUNTY.

ABERNANT. ABERNANT MINE.

Sample.—Bituminous coal; Warrior field; analysis No. 14717 (p. 19).

Mine.—Abernant, a slope mine in sec. 18, T. 20 S, R. 6 W., at Abernant, seven-eighths of a mile south of Yolande.

Coal bed.—Jagger. Carboniferous age, Pottsville group. Thickness of coal mined, 6 to 7 feet; dip, 14° NW. The coal has no cleat, but has several shale partings. Roof-shale, which sometimes comes down and gets mixed with the coal in mining; above the shale is a sandstone cap rock. Floor, hard blue sandstone, which did not mix with the coal in loading.

The bed was measured and sampled at one point in the mine by E. B. Sutton on August 15, 1912, as described below:

Section of coal bed in Abernant mine.

Laboratory No	14717	
Roof, sandstone.	*Ft.*	*in.*
Bone	[a] 0	1½
Coal	0	8
Mother coal	[a] 0	1
Coal	0	5
Shale	[a] 0	3
Coal	1	0
Shale	[a] 0	1
Coal	0	11
Shale	[a] 0	1
Coal	1	8
Shale	[a] 0	4
Coal	0	2
Shale	[a] 0	2
Coal	0	8
Floor, sandstone.		
Thickness of bed	6	7½
Thickness of coal sampled	5	6

[a] Not included in sample.

Section A (sample 14717) was measured at the face of right entry 13.

Notes.—At the time the mine was sampled the coal was undercut by hand and blasted down with a permissible explosive. The tipple was a wooden structure. All coal was shipped as run-of-mine. Two men were employed to trim the coal and pick "slate" from the cars. The average daily output was 300 tons a day, with a capacity of 500 tons.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 39, 352.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 260, 1905, p. 375, and Bull. 400, 1910, p. 170.

ALASKA.

ALASKA PENINSULA.

CHIGNIK BAY. WARNER CLAIM.

Sample.—Bituminous coal; Alaska Peninsula field; analysis No. 12742 (p. 19).

Mine.—Warner claim, Chignik Bay.

Coal bed.—Not named. Cretaceous age, Chignik (?) formation.

Notes.—Sample 12742 was taken at the Warner claim on November 1, 1911. No further information available.

The coal beds of the Chignik Bay region are described in U. S. Geol. Survey Bull. 467, 1911, p. 109.

BERING RIVER.

BARRETT CREEK. CUNNINGHAM CLAIMS.

Sample.—Semibituminous coal; Bering River field; analysis No. 12716 (p. 19).

Locality.—Cunningham claims, on Barrett Creek.

Coal bed.—Unnamed. Tertiary age, Kushtaka formation. Thickness, about 5 feet. A number of beds outcrop on this creek.

Notes.—The bed was sampled on November 4, 1911. The sample was taken at an outcrop on Barrett Creek, three-fourths of a mile above its junction with Clear Creek. The bed was about 5 feet thick at this point.

For a description of the geologic relations of this coal bed, see Report on Coal in Alaska for Use in United States Navy: House Document No. 876, 1914, p. 38.

BARRETT CREEK. CUNNINGHAM CLAIMS.

Sample.—Semibituminous coal; Bering River field; analysis No. 12709 (p. 19).

Locality.—Cunningham claims, Barrett Creek.

Coal bed.—Unnamed. Tertiary age, Kushtaka formation. Thickness about 2 feet. This bed lies above the bed represented by sample 12716.

Notes.—The bed was sampled at one point on November 3, 1911. The sample was taken at a point about 100 feet up the creek, measured across the dip, from the place where sample 12716 was taken. The bed was about 2 feet thick at the point sampled.

For a description of the geologic relations of this coal bed, see Report on Coal in Alaska for Use in United States Navy: House Document No. 876, 1914, p. 38.

BARRETT CREEK. CUNNINGHAM CLAIMS.

Sample.—Semibituminous coal; Bering River field; analysis No. 12707 (p. 19).

Locality.—Cunningham claims on Barrett Creek.

Coal bed.—Unnamed bed. Tertiary age, Kushtaka formation. The bed outcrops above the one represented by sample 12709.

Notes.—The bed was sampled at one point on November 3, 1911. The sample was taken at a point 15 to 20 feet, measured across the strike, above the bed represented by sample 12709.

For a description of the geologic relations of this coal bed see Report on Coal in Alaska for Use in United States Navy: House Document No. 876, 1914, p. 38.

Barrett Creek. Cunningham Claims.

Sample.—Semibituminous coal; Bering River field; analysis No. 12708 (p. 19).

Location.—Cunningham claims on Barrett Creek.

Coal bed.—Unnamed. Tertiary age, Kushtaka formation. The bed lies between the beds represented by samples 12707 and 12714.

Notes.—The bed was sampled at one point on November 3, 1911. The sample was taken from an outcrop on the creek, at a point between the third and fifth seams, about 350 feet, measured along the creek, or between 100 and 125 feet, measured across strike, below fifth bed, and probably between 100 and 150 feet, measured across strike, above the third bed (noted from memory).

For a description of the geologic relations of this coal bed see Report on Coal in Alaska for Use in United States Navy: House Document No. 876, 1914, p. 38.

Barrett Creek. Cunningham Claims.

Sample.—Semibituminous coal; Bering River field; analysis Nos. 12710 and 12714 (p. 19).

Locality.—Cunningham claims on Barrett Creek.

Coal bed.—Unnamed. Tertiary age, Kushtaka formation.

Notes.—The bed was sampled at two points on November 4, 1911. Sample 12714 was taken from an outcrop east of Barrett Creek, about 350 feet up the creek, and about 125 to 150 feet, measured across the strike, from the fourth bed on this creek, and represents 3 to 4 feet of coal next the roof or hanging wall opposite the part represented by sample 12710. There was a band of shale in the middle of the bed 1 to 4 feet thick.

Sample 12710 was taken between the foot wall or floor and the band of shale in the middle of the bed, and represents a bench of coal about 3 feet thick.

For a description of the geologic relations of this coal bed see Report on Coal in Alaska for Use in United States Navy: House Document No. 876, 1914, p. 38.

Barrett Creek. Cunningham Claims.

Sample.—Semibituminous coal; Bering River field; analysis No. 12718 (p. 19).

Locality.—Cunningham claims, on Barrett Creek.

Coal bed.—Unnamed. Tertiary age, Kushtaka formation.

Notes.—The bed was sampled at one point on November 4, 1911. Sample 12718 was taken 20 to 30 feet, measured across strike, above points where samples 12710 and 12714 were taken, about three-quarters mile above mouth of creek.

For a description of the geologic relations of this coal bed see Report on Coal in Alaska for Use in United States Navy: House Document No. 876, 1914, p. 38.

Barrett Creek. Cunningham Claims.

Sample.—Semibituminous coal; Bering River field; analysis No. 12712 (p. 19).

Locality.—Cunningham claims, on Barrett Creek.

Coal bed.—Unnamed. Tertiary age, Kushtaka formation.

Notes.—The coal bed was sampled on November 3, 1911. The sample was taken from a point about 150 feet, measured upstream, or 50 feet, measured across the strike, n points where samples 12710 and 12718 were taken.

r a description of the geologic relations of this coal bed see Report on Coal in a for Use in United States Navy: House Document No. 876, 1914, p. 38.

BRANCH OF CLEAR CREEK. CUNNINGHAM CLAIMS.

Sample.—Semibituminous coal; Bering River field; analysis No. 12711 (p. 19).

Locality.—Cunningham claims, on creek which empties into Clear Creek about 1,000 feet above mouth of Barrett Creek.

Coal bed.—Unnamed. Tertiary age, Kushtaka formation. Thickness at outcrop, 15 feet. The coal in the bed was crushed.

Notes.—The bed was sampled on November 3, 1911. The sample was taken at a point about 3,000 feet northeast of the point on Barrett Creek where sample 12712 was taken.

For a description of the geologic relations of this coal bed see Report on Coal in Alaska for Use in United States Navy: House Document No. 876, 1914, p. 38.

CARBON MOUNTAIN. NO. 1 OPENING.

Sample.—Semibituminous coal; Bering River field; analysis No. 12732 (p. 19).

Locality.—No. 1 opening, on Carbon Mountain.

Coal bed.—Unnamed. Tertiary age, Kushtaka (?) formation.

Notes.—The bed was sampled on November 7, 1911, at No. 1 opening. The bed or lens was 10 or 12 feet thick at this point.

For a description of the geologic relations of this coal bed see Report on Coal in Alaska for Use in United States Navy: House Document No. 876, 1914, p. 45.

CLEAR CREEK. OUTCROP.

Sample.—Semianthracite coal; Bering River field; analyses Nos. 12713, 12715, and 12717 (p. 20).

Locality.—Clear Creek, 4½ miles from mouth of creek.

Coal bed.—Unnamed. Tertiary age, Kushtaka formation.

Thickness, 10 to 13 feet. The bed outcrops just below the main (lower) falls on Clear Creek, about 4½ miles above the mouth of the creek, in the east wall of the gorge, and had not been found in the west wall. The hanging wall or roof is 3 to 4 feet of diabase sill.

Just below the diabase sill or roof is a layer of natural coke, 6 to 10 inches thick.

Notes.—Three samples were taken from this bed on November 4, 1911. Sample 12713 represents the layer of natural coke. Sample 12715 represents 6 to 8 inches of the coal next to the coke. Sample 12717 represents coal from the main part of the bed.

For a description of the geologic relations of this coal bed see Report on Coal in Alaska for Use in United States Navy: House Document No. 876, 1914, p. 41.

CUNNINGHAM CLAIM.

Sample.—Semibituminous coal; Bering River field; analysis No. 12739 (p. 20).

Locality.—Cunningham claim.

Coal bed.—Unnamed.

Notes.—The bed was sampled on November 8, 1911. The sample was taken at the first crosscut off the entry.

No further information available.

GLACIER CREEK.

Sample.—Anthracite; Bering River field; analysis No. 12734 (p. 20).

Locality.—Glacier Creek.

Notes.—This sample was taken on November 8, 1911, from a bowlder of anthracite

HARTLINE No. 1 MINE.

Sample.—Semibituminous coal; Bering River field; analysis No. 12724 (p. 20).

Mine.—Hartline No. 1.

Notes.—The bed was sampled at one point on November 6, 1911. No further information available.

HARTLINE No. 2 MINE.

Sample.—Semibituminous coal; Bering River field; analysis No. 12726 (p. 20).

Mine.—Hartline No. 2.

Notes.—The bed was sampled at one point on November 6, 1911. No further information available.

HARTLINE No. 3 MINE.

Sample.—Semibituminous coal; Bering River field; analysis No. 12725 (p. 20).

Mine.—Hartline No. 3.

Notes.—The bed was sampled at one point on November 6, 1911. No further information available.

HARTLINE No. 4 MINE.

Sample.—Semibituminous coal; Bering River field; analysis No. 12727 (p. 20).

Mine.—Hartline No. 4.

Notes.—The bed was sampled at one point on November 6, 1911. No further information available.

HARTLINE No. 5 MINE.

Sample.—Semibituminous coal; Bering River field; analysis No. 12728 (p. 20).

Mine.—Hartline No. 5.

Notes.—The bed was sampled at one point on November 7, 1911. No further information available.

HARTLINE No. 6 MINE.

Sample.—Semibituminous coal; Bering River field; analysis No. 12723 (p. 20).

Mine.—Hartline No. 6.

Notes.—The bed was sampled at one point on November 6, 1911. No further information available.

HUNTS MINE.

Sample.—Semibituminous coal; Bering River field; analysis No. 12729 (p. 20).

Notes.—A sample was taken at the mine on November 7, 1911. No further information available.

MOUNT ANN. TOP OF MOUNTAIN.

Sample.—Anthracite; Bering River field; analyses Nos. 12719 and 12733 (p. 20).

Locality.—Mount Ann.

Notes.—Sample 12719 was taken near the top, and sample 12733 at the top, of Mount Ann on November 7, 1911.

MOUNT ANN. SIDE OF MOUNTAIN.

Sample.—Semianthracite coal; Bering River field; analysis No. 12720 (p. 20).

Locality.—Mount Ann.

Notes.—This sample was taken on the side of Mount Ann on November 4, 1911.

MOUNT HAMILTON. McDONALD MINE.

Sample.—Semibituminous coal; Bering River field; analysis Nos. 12722, 12730, and 12731 (p. 21).

Mine.—McDonald, one-half mile south of U. S. L. M., Christopher group, near south line, top of ridge, on Mount Hamilton.

Coal bed.—Unnamed. Tertiary age, Kushtaka formation. Thickness about 15 feet. Nearly vertical.

The bed was sampled at three points in the mine on November 6, 7, and 8, 1911. Sample 12722 was taken at the face of the entry. No further information available.

ST. MARYS CREEK. HARTLINE NO. 7 MINE.

Sample.—Semibituminous coal; Bering River field; analysis No. 12721 (p. 21).

Mine.—Hartline No. 7.

Coal bed.—Unnamed. Tertiary age.

Notes.—The bed was sampled at one point on November 6, 1911. No further information available.

TROUT CREEK. CUNNINGHAM PROSPECT TUNNELS NO. 4 AND NO. 5.

Sample.—Semibitumious coal, analyses Nos. 15355, 15356, 15357, 15358, 15359, and 15360 (p. 21).

Locality.—Prospect tunnels No. 4 and No. 5, on the Cunningham claims, about one-fourth of a mile down the creek from the Cunningham cabin on Trout Creek. No. 4 tunnel is about 100 feet below No. 5 tunnel.

Coal bed.—Unnamed bed. Tertiary age, Kushtaka formation. The thickness of the bed as mined in these tunnels average 6 feet 9 inches. The roof was a treacherous shale; the floor a sandstone.

The bed was measured and sampled at four points in tunnel No. 4 and at two points in tunnel No. 5 by W. A. Selvig on November 12 to 22, 1912, as described below:

Section of coal bed in prospect tunnel No. 4, Cunningham claim, Trout Creek.

Section	A		B		C		D	
Laboratory No.	15355		15356		15357		15358	
Roof; shale, sandstone, and coal.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	8	2	5	...	..	1	0
Charcoal, dirt, and shale	[a] 0	2½	[a] 0	5	[a] 2	3	[a] 0	5
Coal	1	2	1	8	5	8½	1	11
Charcoal, shale, and "sulphur"	[a] 0	1½	[a] 0	4	[a] 0	½	[a] 0	3
Coal	1	6	...	..	2	7¼	3	8
Floor, sandstone and coal.								
Thickness of bed	5	8	4	10	10	7¼	7	3
Thickness of coal sampled	5	4	4	1	8	3¾	6	7

[a] Not included in sample.

Section A (sample 15355) was measured in the chute between timber sets 19 and 20, 76 feet from the drift mouth and 10 feet from the entry.

Section B (sample 15356) was measured on the rib of the right crosscut between timber sets 18 and 19, 72 feet from the drift mouth and 17 feet from the entry.

Section C (sample 15357) was measured on the rib near the face of the right crosscut between timber sets 11 and 12, 44 feet from the drift mouth.

Section D (sample 15358) was measured in the right crosscut between timber sets 25 and 26, 100 feet from the drift mouth and 11 feet from the entry.

Section of coal bed in prospect tunnel No. 5, Cunningham claim, Trout Creek.

Section	A		B	
Laboratory No.	15359		15360	
Roof, shale and coal.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	8	...	..
Shale and dirt	[a]0	8	...	..
Coal	2	7	4	0
Charcoal and shale	[a]1	7	[a]1	7
Coal	...	..	1	3
Floor; coal.				
Thickness of bed	7	6	6	10
Thickness of coal sampled	5	3	5	3

[a] Not included in sample.

Section A (sample 15359) was measured in the chute to the left of the entry between timber sets 21 and 22, 84 feet from the drift mouth and 17 feet up chute.

Section B (sample 15360) was measured in the left crosscut between timber sets 13 and 14, 52 feet from the drift mouth and 5 feet from the entry.

The coal beds of the Trout Creek region are described in U. S. Geol. Survey Bull. 335, 1908, p. 72.

MATANUSKA.

ANTHRACITE RIDGE. OUTCROP.

Sample.—Semianthracite coal; Matanuska field; analysis No. 12745 (p. 22).

Locality.—Anthracite Ridge, Matanuska Valley.

Coal bed.—Not named.

Notes.—The bed was sampled on November 1, 1911.

The coal beds of the Anthracite Ridge region are described in U. S. Geol. Survey Bull. 327, 1907, pp. 52–56.

ANTHRACITE RIDGE. OUTCROP.

Sample.—Bituminous coal; Matanuska field; analysis No. 12750 (p. 22).

Locality.—Anthracite Ridge, Matanuska Valley.

Coal bed.—Not named.

Notes.—This bed was sampled on October 27, 1911.

The coal beds of the Anthracite Ridge region are described in U. S. Geol. Survey Bull. 327, pp. 52–56.

ANTHRACITE RIDGE. OUTCROP.

Sample.—Semibituminous coal; Matanuska field; analysis No. 12753 (p. 22).

Locality.—Anthracite Ridge.

Coal bed.—Unnamed.

Notes.—The bed was sampled on October 24, 1911.

The coal beds of the Anthracite Ridge region are described in U. S. Geol. Survey Bull. 327, 1907, pp. 52–56.

ANTHRACITE RIDGE. OUTCROP.

Sample.—Semianthracite coal; Matanuska field; analysis No. 12746 (p. 22).

Locality.—Anthracite Ridge, Matanuska Valley.

Coal bed.—Not named.

Notes.—The bed was sampled at the outcrop near the middle of the south face of the ridge. Elevation (by barometer), 3,700 feet.

The coal beds of the Anthracite Ridge region are described in U. S. Geol. Survey Bull. 327, 1914, pp. 52–56.

ANTHRACITE RIDGE. OUTCROP.

Sample.—Semianthracite coal; Matanuska field; analysis No. 12757 (p. 22).

Locality.—Outcrop on Anthracite Ridge.

Coal bed.—Not named.

Notes.—The bed was sampled on October 26, 1911. The sample was taken at the outcrop, near the middle of the south slope. Elevation (by barometer), 4,100 feet.

The coal beds of the Anthracite Ridge region are described in U. S. Geol. Survey Bull. 327, 1914, pp. 52–56.

CHICKALOON CREEK. OUTCROP.

Sample.—Bituminous coal; Matanuska field; analyses Nos. 12752 and 12764 (p. 22).

Locality.—Outcrop at bend of Chickaloon Creek, one-half mile above Watson Camp.[a]

Coal bed.—Not named. Tertiary age, Chickaloon formation.

The bed was measured and sampled by J. A. Holmes on November 1, 1911.

Beginning on the south side of a series of beds of shale and sandstone, 180 to 200 feet thick, and measuring southward along the face of the bluff from a nearly vertical bed of sandstone 12 feet thick, this section was as follows:

Section of coal bed ½ mile above Watsons Camp.

	Ft.	*in.*
Shale	0	9
Bony coal and streaks of coal	0	10
Impure and other coal	1	0
Coal	[a]2	9
Shale	1	4
Coal	0	2
Shale	0	1
Coal	0	4
Shallow coal	0	9
Bone	0	1
Coal	1	0
Shale and sandstone ("horse")	9	6
Coal	0	4
Shale	1	0
Coal	0	6
Shale	0	4
Coal	0	9
Shale with streaks of coal	1	4
Coal	0	8
Shale	0	2
Coal	[b]4	10
	28	6

[a] Included in sample 12753.

[b] Included in sample 12764.

Notes.—For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 327, 1907, p. 44; Bull. 500, 1912, p. 78.

CHICKALOON CREEK. WATSON TUNNEL NO. 4.

Sample.—Semibituminous coal; Matanuska field; analysis No. 12758 (p. 22).

Locality.—Watson Tunnel No. 4, near Watson Camp, Chickaloon Creek.

Coal bed.—Unnamed. Tertiary age, Chickaloon formation. Thickness, about 10 feet. The bed contained 4 feet 6 inches of crushed coal and two or three bands of bony coal. Strike, east and west; dip, 80° N. Floor and roof, carbonaceous shale, much jointed and slickensided.

---

[a] See Martin's section, U. S. Geol. Survey Bull. 327, p. 44, Nos. 2 and 6.

Notes.—The sample was taken in the west crosscut off the entry, 111 feet from the entry mouth. The crosscut to the east had caved and the face could not be reached.

The coal beds in the vicinity of Chickaloon Creek are described in U. S. Geol. Survey Bull. 500, 1912, pp. 77-81.

CHICKALOON CREEK. PROSPECT.

Sample.—Semibituminous coal; Matanuska field; analysis No. 12761 (p. 22).

Locality.—Chickaloon Creek.

Coal bed.—Unnamed. Tertiary age, Chickaloon formation.

Notes.—The bed was sampled on November 2, 1911.

The coal beds in the vicinity of Chickaloon Creek are described in U. S. Geol. Survey Bull. 500, 1912, pp. 77-81.

CHICKALOON CREEK. TUNNEL B.

Sample.—Semibituminous coal; Matanuska field; analysis Nos. 12756 and 12760 (pp. 22 and 23).

Locality.—Tunnel B, on Chickaloon Creek.

Coal bed.—Unnamed. Tertiary age, Chickaloon formation.

Notes.—The bed was measured and sampled at one point in the entry on October 25, 1911, as described below:

Section of coal bed in Tunnel B, Chickaloon Creek.

	Ft.	*in.*
Coal, impure	[a]3	3
Bone	0	4
Coal	1	0
Bone, lenticular	0	6
Coal	1	0
Shale	1	0
Coal	1	1
Shale	0	3
Coal	1	8
Shale	1	1
Coal, good	[b]3	10

[a] Included in sample 12760.

[b] Included in sample 12756.

Notes.—For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 327, 1907, p. 5; Bull. 500, 1912, p. 79.

COAL CREEK. PROSPECT.

Sample.—Bituminous coal; Matanuska field; analysis No. 12744 (p. 23).

Locality.—Prospect on Coal Creek.

Coal bed.—Unnamed. Tertiary age, Chickaloon (?) formation.

Notes.—The bed was sampled on October 27, 1911.
available.

The coal beds in the vicinity of Coal Creek are described in U. S. Geol. Survey Bull. 500, 1912, pp. 77-78.

COAL CREEK. PROSPECT.

Sample.—Bituminous coal; Matanuska field; analysis No. 12748 (p. 23).

Locality.—Prospect on Coal Creek.

Coal bed.—Unnamed. Tertiary age, Chickaloon (?) formation.

Notes.—The bed was sampled on November 7, 1911.

The coal beds in the vicinity of Coal Creek are described in U. S. Geol. Survey Bull. 327, 1912, pp. 77-78.

COAL CREEK (?).

Sample.—Bituminous coal; Matanuska field; analysis No. 12743 (p. 23).
Note.—No further information available.

MATANUSKA RIVER. O'BRIEN CLAIMS.

Sample.—Bituminous coal; Matanuska field; analysis Nos. 12755 and 12762 (p. 23).
Locality.—Outcrop 1 mile south of Matanuska River, on O'Brien group of claims.
Coal bed.—Unnamed. Tertiary age, Chickaloon formation.

About 1 mile south of Matanuska River the bed outcrops on the north face of a bluff, about 555 feet above the level of Matanuska River, probably near the 1,600-foot contour line and southwest of the east end of Anthracite Ridge. The coal is exposed just east of a shallow ravine extending up the face of this bluff. Strike, N. 75° E., dip 23° SE.

The bed was measured and sampled at this point by J. A. Holmes in September, 1911, as described below:

Section of coal bed, north face of bluff.

	Ft.	*in.*
Carbonaceous shale	0	12
Coal	0	4
Shale	0	½
Coal	0	10
Shale	1-2	0
Coal	0	9
Shale	0	2
Coal	0	10
Bony coal	0	1½
Coal	2	5
Shale	0	1-2 (?)
Coal	1	1
Bony coal	0	1
Sandstone	0	5-7
Coal	0	7
Bony coal	0	2½
Sandy shale and bony coal	0	2-3
Coal	1	2
Bone	0	1
Coal	4	1
Bone	0	1
Coal	0	2
Bone	0	½
Coal	0	10
Coal, slightly bony	0	2
Coal	0	8
Coal, slightly bony	0	10
Shale	0	2-6
Coal	1	0
Shale, with streaks of coal	1	0
Coal	1+	0

The base of this bed was covered up. The samples include the entire section as given above except the bottom 12 inches.

Sample 12755 represents the upper part of the bed, and sample 12762 the lower part of the bed.

MATANUSKA RIVER. O'BRIEN CLAIMS.

Sample.—Bituminous coal; Matanuska field; analysis No. 12763 (p. 23).
Locality.—Outcrop, on the O'Brien group of claims, Matanuska River.
Coal bed.—Unnamed. Tertiary age, Chickaloon formation.

The bed was measured and sampled by J. A. Holmes on November 2, 1911, as described below:

Section of coal bed at outcrop, south of Matanuska River.

Laboratory No.	12763	
Carbonaceous shale.	*Ft.*	*in.*
Coal	0	10
Shale	4	0
Bony coal with streaks of good coal	2	3
Shale	0	10
Coal	0	9
Bony coal	0	7
Shale with irregular bands of coal	3	5
Coal	3	3
Bony coal	1	7
Shale	0	5
Coal with impure or bony bands	1	5
Shale	3	5
Coal with bony bands	1	6
Shale	1	3
Bony coal	1	6
Coal	1	7
Shale.		

The sample was taken at an outcrop in the west face and bed of a ravine, about 100 feet below the top of the bluff. The point where the sample was taken is one-fourth of a mile south of the point where samples 12755 and 12762 were taken, and is southwest of the east end of Anthracite Ridge. Strike, N. 60 W., dip 20° to 40° SW.

MATANUSKA RIVER. O'BRIEN CLAIMS.

Sample.—Bituminous coal; Matanuska field; analysis No. 12747 (p. 23).

Locality.—Outcrop, O'Brien claims, Matanuska River.

Coal bed.—Unnamed. Tertiary age, Chickaloon formation.

The bed was sampled at one point on October 27, 1911.

Notes.—The sample was taken near and on the west side of the gulch, and 35 to 55 feet above the point where sample 12763 was taken. The bed was partly exposed and had apparently the same strike and dip as the bed represented by sample 12763. A section of the part exposed, measured from above downward, was as follows: Coal, 3½ to 4 feet; shale, 6 to 10 inches; coal, 1 to 3 feet.

MATANUSKA RIVER. O'BRIEN CLAIMS.

Sample.—Bituminous coal; Matanuska field; analysis No. 12749 (p. 23).

Locality.—Outcrop about 1 mile south of Matanuska River, on O'Brien claim.

Coal bed.—Unnamed. Tertiary age, Chickaloon formation.

The bed was measured and sampled at one point on October 27, 1911, as described below:

Section of coal bed at outcrop, 1 mile south of river.

Laboratory No.	12749	
	Ft.	*in.*
Shale with streaks of coal	[a] 2	7
Coal	2	10
Shale	[a] 0	2-5
Coal	[a] 1	0
Shale with bands of coal	[a] 2	0
Shale	[a] 4-5	0
Carbonaceous shale with streaks of coal	[a] 1-2	0

[a] Not included in sample.

The sample was taken from an outcrop in the east face of the gulch, and 50 to 75 above the point (across strata) where sample 12763 was taken and about 50 feet w top of bluff.

Matanuska River. O'Brien Claims.

Sample.—Bituminous coal; Matanuska field; analysis No. 12751 (p. 23).

Locality.—Outcrop one-half mile south of Matanuska River, near O'Brien cabin.

Coal bed.—Not named. Tertiary age, Chickaloon formation.

The bed was measured and sampled at one point by J. A. Holmes on November 1, 1911.

Sample 12751 was taken at a point about one-half mile south of Matanuska River, near a small stream which flows north (toward river) by the T. E. O'Brien cabin on the O'Brien coal claim and some 300 yards up this stream from the point where sample 12754 was taken in the west or right face of the bluff. The bed is exposed from a few feet above the level of the creek to near the top of the bluff. The bed here has a strike nearly east and west and a dip 60° to 70° NNW. The section measured from the north side southward was about as follows:

Section of coal bed, near O'Brien cabin.

Laboratory No.	12751	
Shale.	*Ft.*	*In.*
Coal, impure	[a] 1	0
Shale	[a] 0	4–6
Coal with few thin bony bands	6	0
Igneous rock	[a] 6–8	0
Coal with occasional bands of shale and bone (probably 75 per cent coal)	[a] 14	0
Shale	[a] 1–2	0
Altered rock, light-colored, earthy.		

[a] Not included in sample.

The shale and other rock strata on south side of the bed were faulted.

Matanuska River. O'Brien Claims.

Sample.—Bituminous coal; Matanuska field; analysis 12754 (p. 23).

Locality.—O'Brien claim, one-half mile south of Matanuska River.

Coal bed.—Unnamed. Tertiary age, Chickaloon formation.

The bed was measured and sampled at one point by J. A. Holmes on October 24, 1911.

Sample 12754 was taken from an outcrop on the west slope of a gulch (facing east), one-half mile south of Matanuska River and a short distance up a small stream from the cabin of T. E. O'Brien. The bed outcrops about 100 feet above the level of the creek and shows thick irregular beds of coal interbedded with thin irregular layers of ferruginous sandstone(?), with other thin or nearly vertical beds that resemble somewhat the eruptive rocks seen elsewhere in this field. The beds of coal are irregular and in places massive, and stand out prominently in the natural exposure. Strike nearly east and west. The bed is nearly vertical.

A section across the main beds of coal measured from north to south was as follows:

Section of coal bed one-half mile south of Matanuska River.

Laboratory No.	12754	
Shale, with 5 to 10 inch bands of "iron ore" in more or less nodular masses.	*Ft.*	*in.*
Coal	3	6
Bony coal	[a] 0	11
Carbonaceous shale	[a] 0	6–10
Coal	[a] 0	6–10
Shale	[a] 0	6–10
Coal, pinching out in places	[a] ½–1	0
Shale	[a] ½–2	0
Coal, with irregular bands of bony coal	[a] 1½–2	0
Shale, with streaks of coal	[a] ½–1	0
Impure bony coal	[a] 4	0
Shale, with nodular bands of "iron ore"	[a] 5	10
Bony coal in lenticular masses, 1 to 6 inches thick interbedded in carbonaceous shale	[a] 19	0
Shale, dark colored, impregnated and in places interbedded with nodular bands (1 to 8 inches thick) of "iron ore"	30–40	0

[a] Not included in sample.

MATANUSKA RIVER. O'BRIEN CLAIMS.

Sample.—Bituminous coal; Matanuska field; analysis No. 12759 (p. 23).

Locality.—Outcrop on O'Brien claim, about one-half mile south of Matanuska River.

Coal bed.—Unnamed. Tertiary age, Chickaloon formation.

The bed was measured and sampled at one point by J. A. Holmes on November 2, 1911.

Sample 12759 was taken from an outcrop on the west side and near top of bluff (facing east) across the gulch from the point where sample 12751 was taken. It is probably the same bed. The exposure was prominent, but the boundaries were not clearly defined. A section measured from the north side southward was as follows:

Section of coal bed, west side of bluff.

	Ft.	*in.*
Soft black shale	0	4
Coal	0	8
Shale	1	8
Coal	5	[a] 10
Shale	0	8
Impure coal	0	6
Shale	0	10
Coal	0	9
Shale	0	3
Coal	0	10
Bony coal	0	6
Shale	0	5
Coal	2	6
Shale	0	1
Coal	0	11
Bone	0	1
Coal	2	9
Shale, with irregular bands of bony coal	1-3	0
Coal	0	1-18
Bony coal with streaks of shale	1-3	0
Coal	1	4
Shale	0	2
Coal	1	2
Bony coal	1	2
Coal	0	8

[a] Or more.

Notes.—In the upper part of the bed the coal appears to fold on itself southward and thus gives the appearance of being 25 to 30 feet thicker than would be indicated by the above section.

YOUNG CREEK. OUTCROP.

Sample.—Bituminous coal; Matanuska field; analysis No. 11382 (p. 23).

Locality.—Outcrop near Young Creek; longitude 148° 42′ 12″ west, latitude 61° 47′ 40″ north.

Coal bed.—Unnamed. Tertiary age, Chickaloon formation. Dip, 54° SE.; strike, N. 67° E.

The bed was sampled by G. C. Martin on August 11, 1910, in the vicinity of Young Creek. The sample was cut from a natural outcrop after cleaning off with a pick as far as possible all weathered coal. The bed was not measured at this point, but a typical section measured on the north face of Red Mountain about 4 miles north of the mouth of Young Creek is as follows:

Section of coal bed on north face of Red Mountain, about 4 miles north of mouth of Young Creek.

Roof, shale with ironstone nodules.	Ft.	in.
Coal (exposure obscure; thickness estimated)	7	5
Shale	0	1½
Coal	1	2
Shale	0	1
Coal	0	6
Shale	0	1½
Coal	0	7
Shale	0	¾
Coal	0	4
Shale	0	½
Coal	0	2
Shale	0	¾
Coal	2	0
Thickness of bed	12	8

Notes.—Another coal bed at least 5 feet and possibly 10 feet thick is poorly exposed about 30 feet stratigraphically above this, the intervening rocks being shale with ironstone nodules and sandstone. About 30 feet higher another bed of unknown thickness is present and 50 feet still higher indications of another bed were seen.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 480, p. 129.

COLORADO.

ADAMS COUNTY.

BENNETT. THOMAS MINE.

Sample.—Subbituminous coal; Denver region; analysis No. 13141 (p. 23).

Mine.—Thomas, in sec. 12, T. 1 S., R. 61 W., about 25 miles northeast of Bennett, on the Union Pacific Railroad.

Coal bed.—No name. Cretaceous age, Laramie formation.

The bed was measured and sampled at one point in the mine by G. B. Richardson on October 23, 1911. The sample was from a 4-foot bench of coal. There was coal, reported 2 feet thick, above the bench sampled, and coal, reported 2 feet thick, below it.

The sample was obtained at the working face in the mine, about 100 feet south of the bottom of the shaft, which is 110 feet deep.

Notes.—The coal beds of the Denver Basin are described in U. S. Geol. Survey Bull. 381, 1910, pp. 297-306.

BOULDER COUNTY.

LAFAYETTE. SIMPSON MINE.

Sample.—Subbituminous coal; Denver region; analysis No. 15165 (p. 24).

Mine.—Simpson, a shaft mine in the Northern district; in T. 1 S., R. 69 W.; at Lafayette, on the Colorado & Southern Railway.

Coal bed.—Known as the Simpson or Lower. Cretaceous age, Laramie formation. The bed is practically horizontal. Thickness, 6 to 14 feet, average 12 feet. The characteristic impurities are local bone and "sulphur" partings. Roof, hard gray shale, overlain by sandstone; floor, soft smooth underclay. Particles of the roof and floor did not mix with the coal in loading.

The bed was measured and sampled at one point in the mine by J. C. Roberts on November 15, 1912, as described below:

Section of coal bed in Simpson mine.

Laboratory No.	15165	
Roof, shale.	*Ft.*	*In.*
Coal	[a] 4	2
Coal	4	2
Bone	0	3
Coal	2	5
Floor, clay.		
Thickness of bed	11	0
Thickness of coal sampled	6	10

[a] Not included in sample; is good coal but is mined only when mining pillars on retreating.

Section A (sample 15165) was measured at the face of room 1, off entry 125.

Notes.—The mine is worked by the room-and-pillar system. At the time of sampling, the coal was undercut by air punching machines and broken down with black blasting powder. The undercuttings were loaded out with the coal. All coal was shipped as run-of-mine. There were three loading tracks with a capacity of 30 empty and 30 loaded cars. The mine had approximately 300 acres of undeveloped coal. The daily output was about 450 tons, most of which was taken from pillars.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 54, 55, 398, 399.

For results of tests of other coal from this mine, see mention of specific tests as follows—Steaming tests: U. S. Geol. Survey Bull. 261, p. 80; producer-gas tests: U. S. Geol. Survey Bull. 261, p. 90; Bureau of Mines Bull. 13, pp. 108, 272; briqueting tests: U. S. Geol. Survey Bull. 261, p. 152; coking tests: Bureau of Mines Bull. 5, pp. 21, 51.

DELTA COUNTY.

BOWIE. KING MINE.

Sample.—Bituminous (noncoking) coal; Grand Mesa field; analysis No. 15213 (p. 24).

Mine.—King, a drift mine in the Somerset district, 1 mile from Bowie, on the Denver & Rio Grande Railroad.

Coal bed.—King. Cretaceous age, Mesaverde formation. Average thickness, 10 feet; dip, N. 23° 33′ E.; cleat, N. 82° E. Occasional faults and frequent rolls or horsebacks are encountered. The immediate roof, a bony coal 2 to 6 feet thick, is overlain by 15 feet of sandstone. The floor is bony coal 2 to 6 inches thick, underlain by sandstone. Particles of the roof and floor did not become mixed with the coal in mining or loading. Workable beds of coal occur 20 feet above and 80 feet below the King bed. Cover at point of sampling, 900 feet.

The bed was measured and sampled at one point in the mine by W. D. Schofield on December 7, 1912. The section measured 10 feet 2 inches of clear coal, all of which was included in the sample.

The sample was cut from the face of room 5, off left entry 3, 3,600 feet from the mine mouth.

Notes.—The mine is worked on the room-and-pillar system. At the time of sampling the coal was undercut by hand and blasted down with FFF black blasting powder and a permissible explosive. The tipple had two shaking screens 8 feet wide by 12 feet long; one screen had 4-inch holes and the other had 1-inch holes, about 55 to 60 per cent of the coal passing the screens. No pickers were employed on the cars. The lumps were large and the coal had a good appearance on the cars. There were three loading tracks with a capacity of 30 empty and 60 loaded cars. The mine had a capa- 000 tons a day; the average output being about 450 tons.

There were approximately 1,000 acres of unmined coal tributary to this tipple, about 33 per cent of the coal being obtained from advance workings.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 55, 401.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 341, 1909, p. 330.

DOMINGUEZ. WELLS GULCH MINE.

Sample.—Bituminous coal; Grand Mesa field; analysis No. 11106 (p.24).

Mine.—Wells Gulch; sec. 17, T. 4 S., R. 3 E.; in Wells Gulch, Gunnison Valley, about 2½ miles northeast of Dominguez, which is the nearest station on the Denver & Rio Grande Railroad.

Coal bed.—The geologic age of the bed has not been definitely determined. Thickness, 3 feet 11 inches; roof, sandstone; floor, shale. The bed was measured and sampled at one point in the mine by E. G. Woodruff, on October 19, 1910, as described below:

Section of coal bed in Wells Gulch Mine.

Laboratory No.	11106
Roof, sandstone.	*Ft. in.*
Coal	1 8
Shale, carbonaceous, or bone	[a] 2 3
Floor, shale:	
Thickness of bed	3 11
Thickness of coal sampled	1 8

[a] Not included in sample.

Sample 11106 was taken at the face of the entry, about 200 feet from the mine mouth. At the time of sampling, the mine was not being worked. The face had been exposed for several months, and was cleaned with a pick prior to sampling.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 471, 1912, p. 567.

EL PASO COUNTY.

CALHAN. MOSBY MINE.

Sample.—Subbituminous coal; Colorado Springs field; analysis No. 10732 (p. 24).

Mine.—Mosby, a shaft mine in sec. 18, T. 13 S., R. 62 W., 9 miles south of Calhan, which is the nearest station on the Chicago, Rock Island, & Pacific Railway.

Coal bed.—Mosby. Cretaceous age, Laramie formation. Thickness, 4 feet 8 inches. Roof, sandy shale. The bed was measured and sampled at one point in the mine by G. B. Richardson on August 3, 1910, as described below:

Section of coal bed in Mosby mine.

Laboratory No.	10732
Roof, sandy shale.	*Ft. in.*
Coal	1 2
Parting	[a] 0 1
Coal	1 6
Parting	[a] 0 3
Coal	1 8
Floor, not stated.	
Thickness of bed	4 8
Thickness of coal sampled	4 4

[a] Not included in sample.

The sample was taken about 30 feet from the bottom of the 40-foot shaft at the working face. The mine was worked intermittently.

PIKEVIEW. PIKEVIEW MINE.

Sample.—Subbituminous coal; Colorado Springs field; analysis No. 12099 (p. 24).

Mine.—Pikeview, a shaft mine in sec. 18, T. 13 S., R. 66 W., 1 mile north of Pikeview station, on the Denver & Rio Grande Railroad.

Coal bed.—A. Cretaceous age, Laramie formation. Average thickness, about 12 feet; dip, 4° N., 35° E. The bed contains numerous rolls. Cover at point of sampling, 181 feet. Roof, a thin blue shale, above which is a soft sandstone. The floor is a rough shale and a fire clay and is fairly hard.

The bed was measured and sampled at one point in the mine by J. C. Roberts, on April 12, 1911. The sample was taken at the face of north entry 2, 4,000 feet northwest of the shaft. The bed at this point was 10 feet 6 inches thick, but the sample represents only 7 feet 5 inches, the upper 3 feet of the bed being left for roof.

Notes.—Mining is by the room-and-pillar system. At the time of sampling the coal was undercut in the clay and blasted down with FFF black powder. The coal is soft and lignitic. About 60 per cent of the output was sold as run-of-mine. About 60 per cent of the coal would pass through a 4½-inch screen, leaving 40 per cent domestic lump. Pickers were employed both in the mine and on the car. There were three loading tracks with a capacity of 25 empty and 25 loaded cars. The output was 550 to 600 tons a day. The unmined area covered about 640 acres.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, pp. 322–332.

RAMAH. PURDON MINE.

Sample.—Subbituminous coal; Colorado Springs field; analysis No. 10741 (p. 24).

Mine.—Purdon; sec. 27, T. 11 S., R. 61 W.; 3 miles southwest of Ramah, which is the nearest station on the Chicago, Rock Island & Pacific Railway, and 6 miles northeast of Calhan.

Coal bed.—Locally known as Purdon. Cretaceous age, Laramie formation. Thickness, 6 feet 9½ inches. Roof, sandy shale. The bed was measured and sampled by G. B. Richardson on August 15, 1910, as described below:

Section of coal bed in Purdon mine.

Laboratory No.	10741	
Roof, sandy shale.	*Ft.*	*in.*
Coal	1	0
Shale, sandy	[a]0	1½
Coal, with 5 partings, each less than ½ inch thick	2	8
Shale, sandy, and coal	[a]0	2
Coal with 3 partings, each less than ½ inch thick	2	10
Floor, not stated.		
Thickness of bed	6	9½
Thickness of coal sampled	6	6

[a] Not included in sample.

The above sample was taken at the face of the workings, about 700 feet from the entry.

Notes.—The mine was worked intermittently.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 57, 408.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, pp. 319–335.

FREMONT COUNTY.

CHANDLER. CHANDLER MINE.

Sample.—Subbituminous coal; Canon City field; analyses Nos. 13393, 13394, and 13395 (pp. 24 and 25).

Mine.—Chandler, a shaft mine in sec. 22, T. 19 S., R. 70 W., near Chandler, on a spur of the Denver & Rio Grande Railroad.

Coal bed.—Canon. Cretaceous age, Vermejo formation. Average thickness, 4 feet 3 inches; dip, 4° north. The bed is free from faults but contains rolls and horsebacks. The roof is a "draw slate" 6 to 10 inches thick which comes down with the coal; above this "draw slate" is a cap rock. The floor is a soft, rough, shaly sand rock. Cover at points of sampling, about 700 feet.

The bed was measured and sampled at two points in the mine by J. C. Roberts on February 27, 1912, as described below:

Sections of coal bed in Chandler Mine.

Section	A.		B.	
Laboratory No.	13393		13394	
Roof, "draw slate."	*Ft.*	*in.*	*Ft.*	*in.*
Bone	[a]0	6	..	..
Coal, clean	4	2	4	9
Floor, shaly sand rock.				
Thickness of bed	4	8	4	9
Thickness of coal sampled	4	2	4	9

[a] Not included in sample.

Section A (sample 13393) was measured at the face of east entry 9.

Section B (sample 13394) was measured at the face of the main slope.

A composite sample was made by combining and mixing face samples 13393 and 13394. The ultimate analysis of this sample is given under laboratory No. 13395.

Notes.—The shaft is 484 feet deep. The coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by electric chain cutting machines and was shot down with a permissible explosive. "Forty per cent" dynamite was used for brushing the roof. The tipple was equipped with bar screens 18 feet long with 2-inch openings and a revolving screen 16 feet long with ¾-inch to 1¼-inch holes. About 40 per cent of the coal passed through the screens, none being shipped as run-of-mine. Pickers were employed on both picking table and car in loading. There were two loading tracks with a capacity of 36 empty cars and 30 loaded cars. The coal had a good appearance and contained large lumps. The average daily output of the mine was 550 tons. About 90 per cent of the coal was from advance workings and 10 per cent from pillars. The life of the mine would be probably 10 years.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 58, 414.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, p. 358.

ROCKVALE. ROCKVALE MINE.

Sample.—Subbituminous coal; Canon City field; analyses Nos. 11938, 11939, and 11941 (p. 25).

Mine.—Rockvale, a slope mine in secs. 25 and 36, T. 19 S., R. 70 W., and secs. 30 and 31, T. 19 S., R. 69 W., at Rockvale, on the Atchison, Topeka & Santa Fe Railway.

Coal bed.—Rockvale. Cretaceous age, Vermejo formation. Average thickness, 3 feet 6 inches; dip, 5° N. 60° W. The roof is sandstone and black shale, which is hard at some places and soft in others, is generally smooth, and does not adhere to the coal. The floor is a mixture of coal and clay and is called "blackjack"; it is tough and usually smooth. Cover, about 320 feet.

The bed was measured and sampled at two places in the mine by J. C. Roberts on March 7, 1911.

Sample 11938 was measured at the face of room 39, off the third dip, about 6,000 feet south from the shaft. The sample represents 3 feet 9½ inches of clear coal.

Sample 11939 was measured at the face of room 31, off the fourth dip, 6,200 feet south of the shaft. The sample represents 3 feet 9 inches of clear coal.

A composite sample was made by combining face samples 11938 and 11939. The results of an ultimate analysis of this sample are given under laboratory No. 11941.

Notes.—The long-wall method of mining is used. At the time of sampling all of the coal produced was from advance workings. The coal was undercut in the clay and broken down by black powder; "40 per cent" dynamite was used in brushing the roof. All of the coal was screened, none being sold as run-of-mine. About 43 per cent of the coal passed through a 3-inch screen, the screenings producing 18 per cent nut coal and 25 per cent slack; 57 per cent of the coal was sold as lump. Pickers were employed to pick the coal as it was loaded on the car. There were two loading tracks with a capacity of 100 empty cars and 50 loaded cars.

The daily output was about 900 tons; the unmined area tributary to the mine was about 1,200 acres.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 59, 415.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, p. 352.

GARFIELD COUNTY.

NEWCASTLE. VULCAN MINE.

Sample.—Bituminous coal; Grand Hogback field; analyses Nos. 12325, 12326, 12327, and 12420 (p. 25).

Mine.—Vulcan; Glenwood Springs district; sec. 1, T. 6 S., R. 91 W.; 2 miles east of Newcastle, on the Colorado Midland Railway.

Coal bed.—Allen. Cretaceous age, Mesaverde formation. Average thickness, about 14 feet. Roof, a poor quality of sandstone; floor, sandstone.

The bed was measured and sampled at three points in the mine by J. C. Roberts on June 14 and 18, 1911.

Sample 12325 was cut from the face of the east entry on the third level, 1,250 feet southeast of the mine mouth. The sample represents 10 feet 6 inches of coal from the lower part of the section.

Sample 12326 was cut from the face of the Allen entry on the second level, 1,700 feet from the mouth of the entry. The sample represents 10 feet of coal from the lower part of the section.

Sample 12420 was cut from the face of room 15, 250 feet up from the entry and 1,000 feet southeast of the mine mouth. The sample represents 10 feet of coal from the middle of the section.

A composite sample was made by combining and mixing face samples 12325 and 12326. An ultimate analysis of this sample is given under laboratory No. 12327.

Notes.—The coal is mined by the room-and-pillar system. The bottom bench of about 6 feet was first mined, then the top bench was taken down and pillars removed. At the time of sampling the entire output was shipped as run-of-mine except what was delivered by wagon for domestic purposes. The coal loaded on wagons was screened over bars 12 feet long with 2-inch openings. There were three loading tracks with a capacity of 20 empty cars and 25 loaded cars. The daily output was about

150 tons. The probable life of the mine was 50 years. All the coal mined was taken from advance workings.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 415, 1910, p. 112.

SOUTH CANYON. SOUTH CANYON MINE.

Sample.—Bituminous (noncoking) coal; Grand Hogback field; analyses Nos. 15166 and 15167 (p. 25).

Mine.—South Canyon, a drift mine in the Glenwood Springs district, in the NW. ¼ sec. 14, T. 6 S., R. 90 W., at South Canyon, 3 miles from the Colorado Midland Railway and connected with the railroad station by trolley line.

Coal bed.—Wheeler; Cretaceous age, Mesaverde formation. Average thickness, 18 feet; dip 55°. There are no cleats or faults but occasional rolls and horsebacks are encountered. The roof (hanging wall) is a hard black shale above which there is a sandstone cap rock. The floor is a smooth, soft, black shale. Particles of the roof and floor did not mix with the coal in mining. Seventy-two feet above this bed and 32 feet underneath are workable beds of coal. Cover at points of sampling, 500 to 550 feet.

The bed was measured and sampled at two points in the mine by J. C. Roberts on November 30, 1912, as described below:

Sections of coal bed in South Canyon Mine.

Section	A		B	
Laboratory No.	15166		15167	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*
Top coal	5	9	[a]10	0
Coal	(b)		7	8
Floor, shale.				
Thickness of bed	..	..	17	8
Thickness of coal sampled	5	9	7	8

[a] Not included in sample. [b] Not measured.

Section A (sample 15166) was measured in the main entry, 800 feet from the portal.

Section B (sample 15167) was measured at the face of the main entry, 1,600 feet from the portal.

Notes.—The mine is worked by the room-and-pillar system. At the time of sampling the coal was shot down with permissible explosives. None of the coal was shipped as run-of-mine. The coal was screened over bars 18 feet long with 4-inch openings, a shaker screen 14 feet long and 6 feet wide with 2½-inch openings and a shaker screen 14 feet long and 6 feet wide with 1-inch openings. Twenty per cent of the coal passed through the 1-inch screen. This fine coal was wasted, as there was no market for it. The coal was picked or trimmed on the car, and the loaded lump coal had a good appearance. There were three loading tracks with a capacity of 15 empty and 15 loaded cars. The unmined area tributary to this opening was about 1 mile long on the strike of the bed. The daily output was 350 tons.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 61, 421, 422.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 415, 1910, p. 130.

GUNNISON COUNTY.

SOMERSET. SOMERSET MINE.

Sample.—Bituminous coal; Grand Mesa field; analyses Nos. 12322, 12323, and 12324 (p. 25).

Mine.—Somerset; a slope mine in the Somerset district, near Somerset, on the Denver & Rio Grande Railroad.

Coal bed.—Not named. Cretaceous age, Mesaverde formation, Bowie shale. Thickness, 8 to 12 feet. Roof, sandstone; floor, bony coal about 8 inches thick.

The bed was measured and sampled at two points in the mine by J. C. Roberts on June 15, 1911, as described below:

Sections of coal bed in Somerset mine.

Section	A	B
Laboratory No.	12322	12323
Roof, sandstone.	*Ft. in.*	*Ft. in.*
Coal	3 0	3 0
Coal, bony	[a]0 3	[a]0 3
Coal	8 9	4 9
Floor, bony coal.		
Thickness of bed	12 0	8 0
Thickness of coal sampled	11 9	7 9

[a] Not included in sample.

Section A (sample 12322) was measured at the face of room 46 off west entry 6, 10,000 feet north of the entry mouth.

Section B (sample 12323) was measured at the face of west entry 9, 4,500 feet north from the mouth.

A composite sample was made by combining face samples 12322 and 12323. The results of an ultimate analysis of this sample are given under laboratory No. 12324.

Notes.—At the time of sampling the coal was shot down with black powder. The output was 1,000 tons a day.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 341, 1909, p. 330.

HUERFANO COUNTY.

OAKVIEW. OAKDALE MINE.

Sample.—Bituminous coal; Trinidad field; analyses Nos. 13526, 13527, 13528, and 13529 (p. 26).

Mine.—Oakdale, a slope and drift mine in the La Veta district, at Oakview, on a spur of the Denver & Rio Grande Railroad, 7 miles west of La Veta.

Coal bed.—Not named. Cretaceous age, Vermejo formation. Average thickness, 12 feet; dip, 15° W.; cleat, north and south. Occasional faults, rolls and horsebacks are encountered. Roof, shale, overlain by sandstone; floor, soft smooth shaly underclay. Particles of both the roof and floor occasionally mixed with the coal in mining. Cover at points of sampling, 100 to 500 feet.

The bed was measured and sampled at three points in the mine by J. C. Roberts on March 8, 1912, as described below:

Sections of coal bed in Oakdale mine.

Section	A	B	C
Laboratory No.	13526	13527	13528
Roof, shale and sandstone.	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	.. ..	([a])	([a])
Coal, clean	13 10	6 6	[b]3 6
Natural coke	.. ..	.. ..	3 6
Floor, shale.			
Thickness of coal mined	13 10	6 6	7 0
Thickness of coal sampled	13 10	6 6	3 6

[a] Not measured. [b] Not included in sample.

Section A (sample 13526) was measured at the face of room 11, off the second "cross," off the main entry.

Section B (sample 13527) was measured at the face of the main entry. The top coal was not mined in advance work and could not be measured.

ection C (sample 13528) was measured at the face of north entry 4. The top coal ot mined in advance work and could not be measured.

A composite sample was made by combining samples 13526 and 13527. The ultimate analysis of this sample is given under laboratory No. 13529.

Notes.—The mine is worked on the room-and-pillar panel system. At the time of sampling the coal was undercut in the coal with punching machines and shot down with black powder. The machine cuttings were loaded with the coal. Twenty-five per cent of the coal was shipped as run-of-mine. The tipple was equipped with two shaking screens each 12 feet long by 5 feet wide, one having 3-inch and the other 1-inch holes, and a revolving screen 12 feet long with ¾-inch holes. Forty per cent of the coal passed through the ¾-inch screen. No pickers were employed at the tipple. There were three loading tracks with a capacity of 20 empty cars and 30 loaded cars. The coal had an excellent appearance and the lumps were large. The average daily production of the mine was 1,200 tons, with a maximum capacity of 1,800 tons. All the coal was from advance workings. The probable life of the mine was 30 years.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 65, 435.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, p. 419.

JACKSON COUNTY.

COALMONT. RIACH MINE.

Sample.—Subbituminous coal; North Park field; analysis No. 12601 (p. 26).

Mine.—Riach, a slope mine in the Coalmont district, in the NW. ¼ of SW. ¼ sec. 24, T. 7 N., R. 81 W.; at Coalmont, on the extension of the Laramie, Hahn's Peak & Pacific Railway.

Coal bed.—Known as the Riach. Late Cretaceous or early Tertiary age, Coalmont formation. Both roof and floor are coal. Thickness, reported 77 feet; dip, 18° northeast.

The bed was sampled at one point in the mine by A. L. Beekly on August 18, 1911. The sample was collected from the north breast on a freshly stripped, fairly dry face, and represents 7 feet of coal.

Notes.—The mine had a capacity of about 800 tons a day. A considerable part of the output was sold for domestic use in the park and in various towns along the main line of the Union Pacific Railroad.

COALMONT. MITCHELL MINE.

Sample.—Subbituminous coal; North Park field; analysis No. 12539 (p. 26).

Mine.—Mitchell; in SW. ¼ SE. ¼ sec. 24, T. 8 N., R. 82 W.; 8 miles northwest of Coalmont and 15 miles southwest of Walden.

Coal bed.—Mitchell. Late Cretaceous or early Tertiary age, Coalmont formation, The bed consists of an upper bench 8 feet thick separated from a lower 2⅓-foot bench by 10 inches of carbonaceous shale. The shale parting is used as the floor of the mine and about 7 feet of the upper bench is mined, the upper foot being left for roof. Dip, 11° northeast. Strike, north 40° west.

The bed was measured and sampled by A. L. Beekly on August 16, 1911, as described below:

Section of coal bed in the Mitchell mine.

Laboratory No.	12539
Roof, dark, micaceous, sandy shale.	*Ft. in.*
Coal, clean and black	3 6
Coal, soft and laminated	2 6
Coal, hard, black	2 0
Shale, carbonaceous, laminated	[a] 0 10
Coal, hard	[a] 2 4
Floor, shale.	
Thickness of bed	11 2
Thickness of coal sampled	8 0

---

[a] Not included in sample.

The sample was collected in the entry, 275 feet northeast of the mine mouth. The mine was worked intermittently.

HIGHO. MONAHAN MINE.

Sample.—Subbituminous coal; North Park field; analysis No. 12540 (p. 26).

Mine.—Monahan, in the SE. ¼ SE. ¼ sec. 31, T. 10 N., R. 81 W., 4 miles northwest of Higho post office and 18 miles northwest of Walden.

Coal bed.—Monahan. Late Cretaceous or early Tertiary age. Thickness, 4 feet 6 inches; strike N. 15° W.; dip, 22° N.; roof, buff shale; floor, sandstone.

The bed was sampled at one point in the mine by A. L. Beekly on August 3, 1911, the sample representing 4 feet 6 inches of coal.

Notes.—The sample was collected from the face of the entry, which was 125 feet long and was on the dip of the bed. The coal at the face was hard, black, and clean.

WALDEN. MCCALLUM MINE.

Sample.—Subbituminous coal; North Park field; analysis No. 12774 (p. 26).

Mine.—McCallum, a slope mine; McCallum anticline district, NE. ¼ NE. ¼ sec. 18, T. 9 N., R. 78 W.; about 5 miles northeast of Walden.

Coal bed.—Sudduth. Late Cretaceous or early Tertiary age. Base of Coalmont formation. Thickness, reported 35 feet; strike, north 50° west; dip, 18° northeast. Both roof and floor are coal.

The bed was sampled by A. L. Beekly on October 16, 1911.

Notes.—The sample was collected from a fresh face in the entry, 50 feet from the foot of the slope, which was 50 feet long and dips 18°. The sample represents 7 feet of coal.

WALDEN. MARR MINE.

Sample.—Subbituminous coal; North Park field; analysis No. 12415 (p. 27).

Mine.—Marr; McCallum anticline district, in the NW. ¼ NE. ¼ sec. 35, T. 9 N., R. 78 W.; 8½ miles east of Walden.

Coal bed.—Sudduth. Late Cretaceous or early Tertiary age, Coalmont formation. The bed is reported to be 53 feet thick and to consist throughout of a good grade of coal, which is free from partings except for several 1-inch sandy layers near the top. Dip, 56° east.

The bed was sampled by A. L. Beekly on June 27, 1911, the sample representing 6 feet of coal.

Notes.—The sample was collected from a clean surface just inside the entry mouth and about 15 feet from the top of the bed. Forty feet of this bed is exposed in an open cut; the base is covered and inaccessible. The mine consisted of two entries; both were filled with water at the time of sampling.

WALDEN. SUDDUTH MINE.

Sample.—Subbituminous coal; North Park field; analysis No. 12414 (p. 27).

Mine.—Sudduth; a drift mine in the McCallum anticline district, in NW. ¼ SW. ¼ sec. 15, T. 9 N., R. 78 W.; 7½ miles east of Walden.

Coal bed.—Sudduth. Late Cretaceous or early Tertiary age, Coalmont formation. Thickness, reported 50 feet; dip, 85° northeast.

The bed was sampled by A. L. Beekly on June 27, 1911.

Notes.—The mine consisted of an entry or room driven horizontally about 70 feet into the bed. The coal exposed in the mine was clean, hard, and glossy black. The sample was collected from a clean face at the end of the entry and represents 20 feet of coal.

WALDEN. WINSCOM MINE.

Sample.—Subbituminous coal; North Park field; analysis No. 12775 (p. 27).

Mine.—Winscom; McCallum anticline district, SW. ¼ NE. ¼ sec. 14, T. 8 N., R. 78 W.; 10½ miles southeast of Walden.

Coal bed.—Winscom. Late Cretaceous or early Tertiary age, Coalmont formation. Roof, coal; floor, shale. Strike, nearly north and south. Dip, 25° to 30° east.

The bed was measured and sampled by A. L. Beekly on October 16, 1911, as described below:

Section of coal bed in the Winscom mine.

Laboratory No.	12775	
Roof, coal.	*Ft.*	*in.*
Clay	[a]0	10
Coal	0	4
Clay, carbonaceous	[a]0	3
Coal	0	4
Shale, carbonaceous	[a]0	2
Coal	1	0
Shale, carbonaceous	[a]0	7
Coal	0	11
Floor, carbonaceous shale.		
Thickness of bed	4	5
Thickness of coal sampled	2	7

[a] Not included in sample.

Notes.—Sample was collected in the entry, 125 feet from the mouth of the mine.

JEFFERSON COUNTY.

MORRISON. WHITE ASH MINE.

Sample.—Subbituminous coal; Denver region; analysis No. 16615 (p. 27).

Mine.—White Ash, a shaft mine in secs. 23, 24, 25, and 26, T. 4 S., R. 70 W., 2 mile. from Morrison, 1 mile from Colorado & Southern Railway switch. Not on any railroads

Coal bed.—Jumbo. Cretaceous age, Laramie formation. Average thickness, 15 feet; dip, 86°. No rolls or horsebacks have been encountered. Roof (hanging wall), clay 3 inches thick, overlain by shale; above the shale is a sandstone cap rock. Small particles of the shale gradually break off on exposure. Floor (foot wall), a hard smooth underclay. Particles of the floor and roof did not mix with the coal in loading.

The bed was measured and sampled at one point in the mine by J. C. Roberts on March 12, 1913, as described below:

Section of coal bed in White Ash mine.

Laboratory No.	16615	
Roof, clay and shale.	*Ft.*	*in.*
Coal	[a]5	6
Coal	10	6
Floor, underclay.		
Thickness of bed	16	0
Thickness of coal sampled	10	6

[a] Not included in sample.

Sample 16615 was taken in a stope, 30 feet from the second level and 75 feet from the shaft.

Notes.—At the time of sampling the coal was shot off the solid with black blasting powder. The coal was screened through a bar screen 10 feet long with 1-inch openings, about 10 to 15 per cent passing through the screen. No pickers were employed. The coal had a good appearance on the wagons. The area to be mined was approximately 2 miles long on the strike. The output in the immediate future was to be derived from advance workings.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, p. 297.

LA PLATA COUNTY.

DURANGO. SAN JUAN MINE.

Sample.—Bituminous coal; Durango field; analyses Nos. 14770, 14771, 14772 (p. 27).

Mine.—San Juan, a drift mine 1¼ miles southeast of Durango, on the Rio Grande Southern Railroad.

Coal bed.—Not named. Cretaceous age, Mesaverde formation. Thickness, 3 feet 6 inches to 4 feet 10 inches, average about 4 feet. About the middle of the bed is a layer of bony coal 2 inches thick. The roof is a soft gray shale, which slacks on exposure; above the shale is about 10 inches of bony coal. The immediate roof sticks to the coal and often falls in the rooms. The floor is a hard rough shale. Cover at points of sampling, 200 to 225 feet.

The bed was measured and sampled at two points in the mine by W. D. Schofield on September 11, 1912, as described below:

Sections of coal bed in San Juan mine.

Section	A		B	
Laboratory No.	14770		14771	
Roof, shale, and coal.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	6	4	3
Bone, to shale	[a]0	1	[a]0	2
Coal	1	6	0	9
Floor, black shale.				
Thickness of bed	3	1	5	2
Thickness of coal sampled	3	0	5	0

[a] Not included in sample.

Section A (sample 14770) was measured at the face of the main entry, 1,200 feet west of the mine mouth.

Section B (sample 14771) was measured in room 6, off the first dip entry south, 300 feet from the mine mouth.

A composite sample was made by combining and mixing samples 14770 and 14771. The results of an ultimate analysis of this sample are given under laboratory No. 14772.

Notes.—The coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by hand and shot down with permissible explosives. Dynamite was used for brushing the floor and roof. The undercuttings were loaded out with the coal. About 30 per cent of the output was shipped as run-of-mine. Bar screens 30 feet long with 1¼-inch openings were used; about 60 per cent of the coal passed the screen. The screenings were coked. The loading track had a capacity of 7 cars and the "empty" track 25 cars. The daily output was about 160 tons. About one-half of the output was from advance workings and one-half from pillars. There was about 140 acres to be mined from this opening.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 315, 1910, p. 384.

HESPERUS. HESPERUS MINE.

Sample.—Bituminous coal; Durango field; analyses Nos. 14773, 14774, and 14775 (p. 27).

Mine.—Hesperus, a drift mine in sec. 14, T. 35 N., R. 11 W., at Hesperus, on the Rio Grande Southern Railroad.

Coal bed.—Hesperus. Cretaceous age, Mesaverde formation. Thickness, 4 feet 6 inches to 6 feet; average, about 5 feet. About 2 feet from the roof is an irregular shale parting. The immediate roof is smooth and does not fall in the rooms; the main cap rock is 2 inches to 2 feet above the coal. The floor is a soft smooth clay which mixed with the coal in loading. Cover at points of sampling, about 100 feet.

The bed was measured and sampled at two points in the mine by W. D. Schofield, on September 24, 1912, as described below.

Sections of coal bed in Hesperus mine.

Section	A		B	
Laboratory No.	14773		14774	
Roof, "draw slate."	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	2	2	1
Shale, carbonaceous	[a] 0	½	[a] 0	1
Coal	3	0	2	5
Floor, clay.				
Thickness of bed	5	2½	4	7
Thickness of coal sampled	5	2	4	6

[a] Not included in sample.

Section A (sample 14773) was measured at the face of room 3, off right entry 4; 4,000 feet from the mine mouth.

Section B (sample 14774) was measured in room 5, off left entry 5; 4,000 feet west of the mine mouth.

A composite sample was made by combining face samples 14773 and 14774. The results of an ultimate analysis of this sample are given under laboratory No. 14775.

Notes.—The coal is mined by the room-and-pillar system. At the time of sampling, the coal was undercut by hand and broken down with FF black blasting powder. None of the coal was shipped as run-of-mine. Bar screens 8 feet long with 3-inch openings and bar screens 8 feet long with 1-inch openings were used, about 60 per cent of the coal passing through the 1-inch screen. There were three loading tracks with a capacity of 20 loaded cars and 40 empty cars. The daily output was about 200 tons. About 60 per cent of the coal was from advance workings and 40 per cent from pillars. The probable lifetime of the mine is 20 years.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 67, 442.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull 316, 1907, p. 386.

PERINS. PERINS PEAK MINE.

Sample.—Bituminous (coking) coal; Durango field; analyses Nos. 14776, 14777, and 14778 (p. 27).

Mine.—Perins Peak, a drift mine in secs. 11 and 14, T. 35 N., R. 10 W., at Perins, 5 miles southeast of Durango, on a branch of the Rio Grande Southern Railroad.

Coal bed.—Peacock. Cretaceous age, Mesaverde formation. Thickness, 1 foot 6 inches to 6 feet 6 inches. The only impurities are irregular "sulphur" balls in pockets. The immediate roof is good and does not fall in the rooms. The floor is soft and hard shale. Particles of the roof and floor did not mix with the coal in loading. Cover at points of sampling, 70 to 120 feet.

The bed was measured and sampled at two points in the mine by W. D. Schofield on September 17, 1912.

Sample 14776 was cut from the face of room 3, off the main entry, 3,200 feet from the mine mouth. The sample represents 5 feet 1 inch of clear coal.

Sample 14777 was cut from the face of room 13, off the main back entry. The sample represents 5 feet 5 inches of clear coal.

A composite sample was made by combining face samples 14776 and 14777. The results of an ultimate analysis of this sample are given under laboratory No. 14778.

Notes.—The room-and-pillar system of mining is used. At the time of sampling the coal was undercut by hand and broken down with black powder and a permissible explosive. Dynamite was used for brushing the floor and roof. The undercuttings were loaded with the coal. Ninety-five per cent of the coal was shipped as run-of-mine. Ninety per cent of the coal going to the screens passed through. Two bar screens, one being 16 feet long with 8-inch openings and the other 16 feet long with ¾-inch openings, were used. Pickers were employed on the cars. The average daily output was 350 tons. About one-third of the coal was from advance workings and two-thirds from pillars. There was possibly 160 acres of unmined coal. There were three loading tracks, with a capacity of 20 loaded cars and 30 empty cars.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 67, 443.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 316, 1907, p. 386.

LAS ANIMAS COUNTY.

COKEDALE. COKEDALE MINE.

Sample.—Bituminous (coking) coal; Trinidad field; analyses Nos. 11768, 11769, 11770, and 11771 (p. 28).

Mine.—Cokedale, a drift mine in sec. 25, T. 33 S., R. 65 W., at Cokedale, on a branch of the Denver & Rio Grande Railroad.

Coal bed.—Known as the Cokedale. Cretaceous age, Vermejo formation. Average thickness, 6 feet. Roof, sandstone; floor, shale. Cover, 40 to 60 feet.

The bed was measured and sampled at three points in the mine by J. C. Roberts on February 24, 1911, as described below:

Sections of coal bed in the Cokedale mine.

Section	A.		B.		C.	
Laboratory No	11768		11769		11770	
Roof, sandstone:	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	4	2	7	2	5
Bone	[a]0	2	0	5	0	7
Coal	0	9	0	4	0	7
Bone	[a]0	7	[a]1	2	[a]0	3
Coal	2	3	0	7	2	3
Bone	..	..	[a]0	6	..	..
Coal	..	..	0	4	..	..
Bone	..	..	[a]0	1½	..	..
Coal	..	..	0	10	..	..
Floor, shale:						
Thickness of bed	6	1	6	10½	6	1
Thickness of coal sampled	5	4	4	9½	5	3

[a] Not included in sample.

Section A (sample 11768) was measured at the face of room 8, off west entry 4.

Section B (sample 11769) was measured at the face of room 21, off west entry 1.

Section C (sample 11770) was measured at the face of room 10, off west entry 6.

A composite sample was made by combining face samples 11768, 11769, and 11770. The results of an ultimate analysis of this sample are given under laboratory No. 11771.

Notes.—At the time of sampling the output was 1,200 tons a day.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 69, 447.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, p. 399.

DELAGUA. DELAGUA MINE.

Sample.—Bituminous (coking) coal; Trinidad field; analyses Nos. 11435, 11436, 11437, and 11443 (p. 28).

Mine.—Delagua, a shaft mine in sec. 15, T. 31 S., R. 65 W., at Delagua, 20 miles north of Trinidad, on the Colorado & Southeastern Railway.

Coal bed.—Known as the Delagua. Cretaceous or Tertiary age, Raton formation. Thickness, 5 feet to 6 feet. Roof, shale 12 to 20 inches thick. Cover at points of sampling, 450 to 500 feet.

The bed was measured and sampled at three points in the mine by J. C. Roberts on December 9, 1910, as described below:

Sections of coal bed in the Delagua Mine.

Section	A		B		C	
Laboratory No	11435		11436		11437	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	10	6	6	2	8
Bone	0	½	..	..	[a]0	4
Coal	2	9½	..	..	2	8
Floor, not stated.						
Thickness of bed	5	8	6	6	5	8
Thickness of coal sampled	5	8	6	6	5	4

[a] Not included in sample.

Section A (sample 11435) was measured at the face of room 1, east entry 24, off north entry 3.

Section B (sample 11436) was measured at the face of east entry 18, off north entry 4.

Section C (sample 11437) was measured at the face of room 5, west entry 3, off north entry 4.

A composite sample was made by combining face samples 11435, 11436, and 11437. The results of an ultimate analysis of this sample are given under laboratory No. 11443.

Notes.—At the time of sampling the output was 1,000 to 1,500 tons a day.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 69, 448.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, p. 410.

For results of tests of other coal from this mine see mention of specific tests as follows—Washing tests: U. S. Geol. Survey Bull. 368, p. 27; coking tests: U. S. Geol. Survey Bull. 368, p. 39.

FORBES. FORBES NO. 9 (OR COX) MINE.

Sample.—Bituminous coal; Trinidad field; analyses Nos. 11926, 11927, 11929, and 11930 (pp. 28 and 29).

Mine.—Forbes, a drift mine in secs. 15 and 16, T. 32 S., R. 64 W., at Forbes, on a spur of the Denver & Rio Grande Railroad.

Coal bed.—Walsen. Cretaceous age, Vermejo formation. Average thickness about 4 feet; dip 1° southwest. One fault showing a displacement of 3 feet has been found. The roof is a hard, smooth, dark-gray shale, overlain by sandstone. The floor is a thin, hard, smooth shale, underlain by 18 inches of coal; beneath the coal is shale. Cover at points of sampling, 300 to 400 feet.

The bed was measured and sampled at three points in the mine by J. C. Roberts on March 16, 1911.

Sample 11926 was cut from the face of the first crosscut, off west entry 1; 2,800 feet southwest of the slope opening. The sample represents 4 feet 4 inches of clean coal.

Sample 11927 was cut from the face of west entry 6; 3,800 feet southwest of the slope opening. The sample represents 3 feet 9 inches of clean coal.

Sample 11929 was taken in room 6, off west entry 4; 3,200 feet southwest of the slope opening. The sample represents 3 feet 11 inches of clean coal.

A composite sample was made by combining face samples 11926, 11927, and 11929. The results of an ultimate analysis of this sample are given under laboratory No. 11930.

Notes.—The room-and-pillar system of mining is employed. At the time the mine was visited the coal was undercut by hand and broken down with black powder; "40 per cent" dynamite was used for brushing the roof and taking up the bottom. Nearly 95 per cent of the coal was shipped as run-of-mine. The coal was friable, about 38 per cent passing through a 2-inch screen. Pickers were employed on the cars in loading. There were three loading tracks, with a capacity of 30 empty cars and 60 loaded cars. About 80 per cent of the coal was recovered, 40 per cent being from advance workings and 40 per cent from pillar workings. The daily output was 600 to 700 tons.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, p. 402.

HASTINGS. HASTINGS MINE.

Sample.—Bituminous (coking) coal; Raton Mesa field; analyses Nos. 12028, 12029, and 12031 (p. 29).

Mine.—Hastings, a slope mine in sec. 25, T. 32 S., R. 64 W., at Hastings, on the Colorado & Southeastern Railroad, with connections to the Colorado & Southern Railway and the Denver & Rio Grande Railroad.

Coal bed.—Berwind (?) and Hastings. Cretaceous age, Vermejo formation.

The Hastings bed averages about 8 feet in thickness and dips 5° west. The roof and floor are shale. Cover at points of sampling, about 800 feet.

The bed was measured and sampled at two points in the mine by J. C. Roberts on April 6, 1911, as described below:

Section of Hastings bed in Hastings mine.

Laboratory No.	12028	
	Ft.	in.
Roof, shale.		
Coal	6	0
Coal, bony	[a]1	0
Coal	3	5
Floor, shale.		
Thickness of bed	10	5
Thickness of coal sampled	9	5

[a] Not included in sample.

The sample was measured on the pillar between south entries 7 and 8, 8,300 feet from the mouth of the slope.

Sample 12031 was taken in south entry 7, at the fifth crosscut, 8,200 feet from the mouth of the slope.

The Berwind (?) bed is about 40 feet below the Hastings. The roof is sandstone; it is smooth and does not adhere to the coal in mining. The floor is a hard, smooth sandstone. The cover is 800 feet thick.

The bed was measured and sampled at one point in the mine by J. C. Roberts on April 6, 1911, as described below:

Section of Berwind (?) bed in Hastings mine.

Laboratory No.	12029	
	Ft.	in.
Roof, sandstone.		
Coal	1	0
Coal, bony	0	1
Coal	0	6
Coal, bony	0	1
Coal	0	6
Coal, bony	0	1
Coal	2	10
Floor, sandstone.		
Thickness of bed	5	1
Thickness of coal sampled	5	1

The above section (sample 12029) was measured at the face of the slope.

Notes.—The double entry, room-and-pillar system of mining is used. At the time of sampling, the coal was undercut with electric chain cutters and shot down with a permissible explosive.

None of the coal was sold as run-of-mine. The coal was screened over a 2½-inch bar screen, about 50 per cent passing through the screen. The screenings were washed with Stewart jigs and yielded a 2-inch product and slack. The capacity of the washery was 400 tons a day. There were coke ovens with a capacity of 300 tons and storage bins with a capacity of 500 tons. There were two loading tracks capable of handling 150 empty and 150 loaded cars.

The capacity of the mine was 1,000 tons a day. There was 640 acres of unmined coal tributary to the main entry.

For results of tests of other coal from this mine, see mention of specific tests, as follows: Washing tests, U. S. Geol. Survey Bull. 368, p. 27; coking tests, U. S. Geol. Survey Bull. 368, p. 45.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 69, 449.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, p. 404.

MORLEY. MORLEY MINE.

Sample.—Bituminous (coking) coal; Trinidad field; analyses Nos. 13361, 13362, 13363, and 13364 (p. 29).

Mine.—Morley, a drift and slope mine at Morley, on the main line of the Atchison, Topeka & Santa Fe Railway.

Coal bed.—Known as the Engle-Starkville. Cretaceous age, Vermejo formation. Average thickness, 4 to 7 feet; dip, 15° to 18° west. The roof is a shale about 18 inches thick; above the shale is sandstone. Floor, shale or sandstone. Particles from the roof and floor did not mix with the coal in mining. The cover at points of sampling ranges from 250 to 450 feet.

The bed was measured and sampled at three points in the mine by J. C. Roberts on February 17, 1912, as described below:

Sections of coal bed in Morley mine.

Section	A		B		C	
Laboratory No	13361		13362		13363	
Roof, 18 inches of coal left for safety; shale and sandstone above.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	0	0	11	5	1
Shale, soft	0	2	0	1	..	..
Coal	3	1	5	1	..	..
Floor, shale and sandstone.						
Thickness of coal mined	5	3	6	1	5	1
Thickness of coal sampled	5	3	6	1	5	1

Section A (sample 13361) was measured at the face of room 2, off third plane, off right entry 4.

Section B (sample 13362) was measured at the face of fifth left entry.

Section C (sample 13363) was measured at the face of fourth right entry; 3,000 feet from the mine mouth.

A composite sample was made by combining and mixing face samples 13361, 13362, and 13363. The results of an ultimate analysis of this sample are given under laboratory No. 13364.

Notes.—The Morley mine is opened on the east side by a drift and on the west side by a slope. The room-and-pillar system of mining is used. At the time of sampling the coal was undercut by hand and broken down with a permissible explosive, which was also used for brushing the roof. Seventy-five per cent of the coal was shipped as run-of-mine, and 25 per cent was screened. Shaker screens, 16 feet long by 6 feet wide, with 3-inch and 1½-inch holes were used; 60 per cent passed through the screens. Pickers were employed in loading screened coal on the cars. The lumps were of medium size and of good appearance. The screenings were coked; they were not washed before coking. There was no storage bin at this mine. There were two tracks, with a capacity of 45 empty and 45 loaded cars. The probable lifetime of the mine is about 25 years.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 69, 450.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, p. 424.

PRIMERO. FIRST EAST, FIRST WEST, AND FIRST NORTH PRIMERO MINES.

Sample.—Bituminous coal; Trinidad field; analyses Nos. 12025, 12027, W31033 to W31043, 14058, 14059, 14060, W31131 to W31151 (pp. 29–32).

Mines.—First East, First West, and First North Primero, drift mines, in secs. 23, 24, 25, and 26, T. 33 S., R. 66 W., at Primero, on the Colorado & Wyoming Railway.

Coal bed.—Primero. Cretaceous or Tertiary age, Raton formation. Average thickness, 7 feet; dip, 4° northwest. Faults, rolls, and horsebacks are frequent. The roof is a hard black shale; above the shale is a sandstone cap-rock. Particles of the shale mix with the coal in mining. The floor is a soft smooth shale, particles of which occasionally mix with the coal in mining. The cover at points of sampling to ranges from 50 to 500 feet at the First West mine; from 500 to 550 feet at the First North mine; and from 600 to 850 feet at the First East mine.

The bed was measured and sampled at 16 points in the mine as follows: 2 points on March 25, 1911, by J. C. Roberts; 5 points in the First West Primero mine on May 16, 1912; 3 points in the First North Primero mine on May 19, 1912; and 6 points in the First East Primero mine on May 19, 1912, by J. C. Roberts and W. D. Schofield; also 9 sets of duplicate samples were taken from cars that were being loaded on May 16 to 19, inclusive, 1912, as described below:

Sample 12025 was cut from the face of room 1, off the second blind back entry. The bed at this point was 5 feet 10 inches thick, all of which was included in the sample.

Sample 12027 was cut from the face of the first west slope, 1,500 feet from the drift mouth.

Sections of coal bed in First East Primero mine.

Section	A		B		C	
Laboratory No.	W31144		W31145		W31146	
Roof, "draw slate" and sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	11	0	9	1	0
Shale	0	½	0	½	0	½
Coal	1	0	3	10	1	2½
Shale	0	½	..	..	..	..
Natural coke	..	..	0	1½	0	1
Coal	3	1	1	8	3	7
Floor, shale.						
Thickness of bed	5	1	6	5	5	11
Thickness of coal sampled	5	1	6	5	5	11

Section A (sample W31144) was measured on a pillar of room 5, off entry B–9, off first blind entry.

Section B (sample W31145) was measured on a chain pillar of east entry B–9.

Section C (sample W31146) was measured at the face of room 4, off east entry B–10.

Sample W31143 was measured on a pillar of right entry 6, between rooms 1 and 2, off third blind entry, off entry B–8. The bed measured 6 feet 1 inch at this point, all of which was included in the sample.

Sample W31147 was measured at the face of room 3, off eleventh east entry. The bed measured 7 feet 4 inches at this point, all of which was included in the sample.

Sample W31149 was measured on a chain pillar of third blind entry, off east entry B-10 The bed measured 7 feet at this point, all of which was included in the sample.

A composite sample was made by mixing face samples W31143, W31144, W31145, W31146, W31147, and W31149. The results of an ultimate analysis of this sample are given under laboratory No. 14060.

Sections of coal bed in First North Primero mine.

Section	A		B		C	
Laboratory No	W31148		W31150		W31151	
Roof, "draw slate" and sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	4	..	..	..	..
Bone	0	1	0	6	..	..
Coal	1	11	2	0	3	5
Bone or "sulphur"	0	½	[a]0	1	[a]0	1½
Coal	0	2	..	..	..	..
Shale	0	½	..	..	..	..
Coal	2	8	2	2	..	..
Bone	0	½	0	½	..	..
Coal	2	8	2	2½	3	7½
Floor, underclay:						
Thickness of bed	7	11	7	0	7	2
Thickness of coal sampled	7	11	6	11	7	½

[a] Not included in sample.

Section A (sample W31148) was measured at the face of room 5, off third back entry, off entry A-12.

Section B (sample W31150) was measured on a pillar of room 7, off entry A-12.

Section C (sample W31151) was measured at the face of entry B-9.

A composite sample was made by combining face samples 31148, 31150, and 31151. The results of an ultimate analysis of this sample are given under laboratory No. 14059.

Sections of coal bed in First West Primero mine.

Section	A		B		C		D		E	
Laboratory No	W31039		W31040		W31041		W31042		W31043	
Roof, sandstone and "draw slate."	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	8	2	5	..	..	..	..	..	..
Bone	0	½	0	1	..	..	..	..	..	..
Coal	0	8	0	1	..	..	..	..	..	..
Bone, "sulphur" band	[a]0	1½	0	½	..	..	..	..	..	..
Coal	1	7	0	6	..	..	..	..	..	..
Shale	[a]0	2	0	½	..	..	..	..	..	..
Coal	..	..	0	8	0	11	2	2½	2	10
Natural coke	..	..	..	..	..	..	[a]0	4½	..	..
Shale	..	..	0	1	[a]0	2	..	..	0	1
Coal	1	6	1	5	3	8	2	5	2	1
Floor, clay and sandstone.										
Thickness of bed	4	9	5	4	4	9	5	0	5	0
Thickness of coal sampled	4	5½	5	4	4	7	4	7½	5	0

[a] Not included in sample.

Section A (sample W31039) was measured at the face of north entry 2.

Section B (sample W31040) was measured at the face of room 10, off first north entry.

Section C (sample W31041) was measured at the face of room 9, off second south entry.

Section D (sample W31042) was measured at the face of room 5, off first right entry, off the first west air course.

Section E (sample W31043) was measured at the face of room 17, off second right entry, off the first west air course.

A composite sample was made by combining and mixing face samples 31039 to 31043, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14058.

Nine samples were taken in duplicate at the mine from the cars while being loaded. Fifty pounds of coal was taken from each of four cars. The four lots were combined, quartered, and sampled in duplicate.

Duplicate samples W31033 and W31034, W31035 and W31036, W31131 and W31132, W31133 and W31134, W31135 and W31136, W31137 and W31138, and W31141 and W31142, were taken from four cars; duplicate samples W31139 and W31140 were taken from one car only; 29 cars being sampled in all.

Notes.—The Primero mines are worked on the room-and-pillar system. At the time of sampling the coal was undercut by hand. Permissible explosives were used for breaking down the coal and for brushing the floor and roof. When the mine was sampled in 1912, all the coal was shipped as run-of-mine, but when screened, 65 per cent of the coal passed through. The screens were bars 18 feet long spaced 1½ inches apart. The screenings were washed and coked at Segundo, the capacity of the coking plant being 1,300 tons a day and the capacity of the washery 1,600 tons a day. Pickers were employed on the cars. The lumps on the cars were of medium size and of good appearance. There were four loading tracks with a capacity of 80 empty and 80 loaded cars. The daily average output was 1,200 tons of coal with a capacity of 1,600 tons. Seventy-five per cent of the output was from pillars and 25 per cent from advance workings. The probable lifetime of the mine was 25 years.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 69–70, 450–451.

For results of tests of coal from this mine see mention of specific tests as follows—Washing tests: Bureau of Mines Bull. 5, p. 32; coking tests: Bureau of Mines Bull. 5, p. 44.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, p. 426.

STARKVILLE. STARKVILLE MINE.

Sample.—Bituminous (coking) coal; Trinidad field; analyses Nos. 11134, 11135, 12196, 12197, and 12198 (p. 32).

Mine.—Starkville, a drift mine at Starkville, on the main line of the Atchison, Topeka & Santa Fe Railway.

Coal bed.—Engle-Starkville. Cretaceous age, Vermejo formation. Average thickness, 6 feet; dip 1° southwest. Roof, smooth shale overlain by sandstone; floor, hard rough shale; cover, at points of sampling, 150 to 550 feet.

The bed was measured and sampled at two points in the mine by H. M. Wolflin (Nos. 11134 and 11135) on October 20, 1910, and at two points by J. C. Roberts (Nos. 12196 and 12197) on May 9, 1911, as described below:

Sections of coal bed in Starkville mine.

Section	A		B		C		D	
Laboratory No.	11134		11135		12196		12197	
Roof, shale and sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Bone	0	3	..	..	..	..	..	..
Coal, clean and bright	0	7	0	6	..	..	0	10
Shale	0	½	..	..	..	..	..	..
Coal, clean	1	¼	..	..	..	..	..	..
Coal, hard and bright	0	¼	0	½	..	..	..	..
Coal, clean	1	2⅝	1	3	..	..	..	..
Bone	[a]0	2¾	..	..	..	..	[a]0	8
Coal, clean	0	7	..	..	..	..	0	7
Bone	[a]0	1½	[a]0	1½	..	..	0	2
Coal, bright	1	5	..	..	..	..	1	9
Bone	0	3¼	..	..	..	..	[a]0	3
Shale	[a]0	1¼	..	..	..	..	..	..
Coal, clean	1	4½	1	2	5	9	0	10
Floor, shale.								
Thickness of bed	7	2⅞	3	1	5	9	5	1
Thickness of coal sampled	6	9⅜	2	11½	5	9	4	2

[a] Not included in sample.

Section A (sample 11134) was measured on the rib of west entry 8, 30 feet outby slant from new entry.

Section B (sample 11135) was measured in south entry 3 near the second crosscut from the new entry.

Section C (sample 12196) was measured in entry I-5 on the pillar between rooms 26 and 27, 15,000 feet southwest of the opening.

Section D (sample 12197) was measured at the face of south entry 1, 1,200 feet southeast of the mouth of the main drift.

A composite sample was made from face samples 12196 and 12197. The results of an ultimate analysis of this sample are given under Laboratory No. 12198.

Notes.—The room-and-pillar system of mining is used. At the time of sampling the coal was undercut by hand; no explosives were used for breaking down the coal. A large part of the output was sold as run-of-mine. About 70 per cent of the coal going to the screens passed through a 2½-inch bar screen; pickers were employed on the cars. The screenings were washed; the capacity of the washery was 700 tons a day; coke ovens, 600 tons; storage bins, 1,400 tons. There were three loading tracks with a capacity of 70 empty and 70 loaded cars.

The average output was 900 tons a day; unmined area, 640 acres.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, p. 396.

TOLLERBURG. TOLLER MINE.

Sample.—Bituminous coal; Trinidad field; analyses Nos. 13253 and 13254 (p. 32).

Mine.—Toller, a shaft mine near Tollerburg, on a spur of the Colorado & Southern Railway.

Coal bed.—Berwind. Cretaceous age, Vermejo formation. Average thickness, 6 feet; dip, 4 to 5 per cent, southwest; cleat, east, and west. Faults, rolls and horsebacks occur frequently. The roof is a hard shale which in places is full of slips. Above this shale is 15 inches of good quality of roof coal; above the roof coal is a cap rock, the cap rock being 5 to 6 feet above the coal mined. The floor is a soft smooth sandstone. Neither the roof nor floor materials mixed with the coal in mining. Cover, at points of sampling, 400 to 450 feet.

The bed was measured and sampled at two points in the mine by J. C. Roberts on January 8, 1912, as described below:

Sections of coal bed in Toller mine.

Section	A		B	
Laboratory No.	13253		13254	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*
Coal, clean	7	0	1	3
Bone	..	..	0	4
Coal, clean	..	..	5	5
Floor, shale.				
Thickness of bed	7	0	7	0
Thickness of coal sampled	7	0	7	0

Section A (sample 13253) was measured at the face of the slope, 2,500 feet from the shaft bottom.

Section B (sample 13254) was measured at the face of north entry 5, 3,000 feet from the shaft bottom.

Notes.—The shaft is 350 feet deep. The coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by hand. Permissible explosives were used for breaking down the coal and for brushing the roof and floor. Ninety per cent of the coal was shipped as run-of-mine. The tipple had shaker screens 15 feet long by 5 feet wide with 3-inch holes. Pickers were employed on the cars in loading.

The lumps were of medium size and had a good appearance. There were three tracks with a capacity of 30 empty cars and 25 loaded cars. The average daily production was 700 tons, with a capacity of 900 tons. Three-fourths of the coal was from advance workings and one-fourth from pillars. About 400 acres remain to be mined.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 381, 1910, p. 403.

MESA COUNTY.

GRAND JUNCTION. PROSPECT.

Sample.—Bituminous coal; Gunnison Valley field; analyses Nos. 11108 and 11109 (p. 33).

Mine.—Prospect, near the junction of the Grand and Gunnison Rivers in sec. 26, T. 1 S., R. 1 W., 1 mile south of Grand Junction, which is the nearest station on the Denver & Rio Grande Railroad.

Coal bed.—Unnamed. Cretaceous age, Dakota (?) formation. Thickness, about 3 feet. Both the roof and floor are carbonaceous shale. Cover, about 30 feet.

The bed was measured and samples were taken at one point in the mine by E. G. Woodruff on October 20, 1910, as described below:

Sections of coal bed in prospect near Grand Junction.

Section	A		B	
Laboratory No.	11108		11109	
Roof, carbonaceous shale.	Ft.	in.	Ft.	in.
Coal	1	11	[a]1	11
Shale	[a]0	1	[a]0	1
Coal	[a]0	10	0	10
Floor, carbonaceous shale.				
Thickness of bed	2	10	2	10
Thickness of coal sampled	1	11	0	10

[a] Not included in sample.

The above samples were taken in the entry, about 125 feet from the mouth of the entry. At the time the samples were taken the prospect was not being worked.

Note.—The coal is hard and black and looks like good coal, but contains a very high percentage of ash.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 471, 1912, p. 568.

GRAND JUNCTION. PROSPECT.

Sample.—Subbituminous coal; Gunnison Valley region; analyses Nos. 11104 and 11105 (p. 33).

Mine.—A prospect opening between Grand Junction and White Water, in sec. 5; T. 2 S., R. 1 E., 5 miles southeast of Grand Junction, which is the nearest station on the Denver & Rio Grande Railroad.

Coal bed.—Unnamed bed. Cretaceous age, Dakota(?) formation. Thickness, 2 feet 6 inches. Roof, sandstone; floor, carbonaceous shale.

The bed was measured and samples were taken from one point in the mine by E. G. Woodruff on October 10, 1910, as described below:

Sections of coal bed in prospect, 5 miles south of Grand Junction.

Section	A		B	
Laboratory No.	11104		11105	
Roof, sandstone.	Ft.	in.	Ft.	in.
Coal	1	3	[a]1	3
Shale, gray	[a]0	3	[a]0	3
Coal	[a]1	0	1	0
Floor, carbonaceous shale.				
Thickness of bed	2	6	2	6
Thickness of coal sampled	1	3	1	0

[a] Not included in sample.

Both of these samples were taken in the entry, about 100 feet from the mouth of the entry. At the time of sampling this prospect was not being worked.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 471, 1910, p. 569.

MOFFAT COUNTY.

AXIAL. BATTLE ERA MINE.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 14528 (p. 33).

Mine.—Battle Era; NW. ¼ sec. 14, T. 4 N., R. 94 W.; in Morgan Gulch, 6 miles west of Axial, 59 miles west and 14 miles south of the terminus of the Denver & Salt Lake Railroad.

Coal bed.—No name. Cretaceous age, Mesaverde formation. Dip, 8½° south.

The bed was measured and sampled at one point in the mine on July 29, 1912, by E. T. Hancock, as shown below:

Section of coal bed in Battle Era mine.

Laboratory No	14528	
Roof, sandy shale.	*Ft.*	*in.*
Coal	2	½
Shale, carbonaceous	[a]0	6
Coal	8	11½
Floor, carbonaceous shale.		
Thickness of bed	11	6
Thickness of coal sampled	11	0

[a] Not included in sample.

The sample was taken in the entry 130 feet northeast of the mine mouth.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 415, 1910, p. 167.

AXIAL. ED COLLOM MINE.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 14529 (p. 33).

Mine.—Ed Collom; SW. ¼ sec. 13, T. 4 N., R. 94 W.; in Collom gulch, 5½ miles northwest of Axial, 14 miles south and 56 miles west of the terminus of the Denver & Salt Lake Railroad.

Coal bed.—No name. Cretaceous age, Mesaverde formation. Dip, about 40° southwest.

The bed was measured and sampled at one point in the mine by E. T. Hancock on July 29, 1912.

The sample was taken in the mine 75 feet northwest of the mine mouth.

The bed was 13 feet 6 inches thick at the point sampled, all of which was included in the sample. The roof was shaly sandstone, the floor was carbonaceous shale. The coal was mined for local use only.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 415, 1910, p. 173.

AXIAL. JAMES MINE.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 12704 (p. 33).

Mine.—James; in sec. 14, T. 3 N., R. 93 W.; on Spring Creek, 4 miles south of Axial, on the Meeker-Axial stage road.

Coal bed.—No name. Cretaceous age; Mesaverde formation. Dip, 13° S., 66° E.

The bed was measured and sampled on October 9, 1911, by E. T. Hancock.

The sample was taken in the main entry 100 feet north of the mine mouth, in 6 feet 4 inches of coal. There was coal above the part sampled. The floor was brown shale.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 79, 476.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 415, 1910, p. 168.

AXIAL. JOE COLLOM MINE.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 14543 (p. 33).

Mine.—Joe Collom; SW. ¼ NE. ¼ sec. 2, T. 3 N., R. 93 W.; on Spring Creek, 1½ miles south of Axial; 65 miles north of the Denver & Rio Grande Railroad.

Coal bed.—Collom. Cretaceous age; Mesaverde formation. Dip, 3½° S., 29° W.

The bed was measured and sampled at one point in the mine on July 30, 1912, by E. T. Hancock, as described below:

Section of coal bed measured near opening of Joe Collom mine.

Laboratory No.	14543	
Roof, brown shale.	*Ft.*	*in.*
Coal	[a]6	9¼
Shale, brown, sandy	[a]0	⅛
Coal	[a]4	4⅛
Coal	8	11
Floor, brown shale.		
Thickness of bed	20	½
Thickness of coal sampled	8	11

[a] Not included in sample.

Only 8 feet 11 inches of the lower bench of the coal bed was exposed in the mine. Only that portion was sampled. The sample was taken 400 feet northwest of the mine mouth.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 79, 476.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 415, 1910, p. 167.

AXIAL. SHAFER MINE.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 14909 (p. 33).

Mine.—Shafer; sec. 31, T. 4 N., R. 92 W.; on Milk Creek, 2 miles east of Axial, 50 miles west and 16 miles south of the western terminus of the Denver & Salt Lake Railroad.

Coal bed.—No name. Cretaceous age; Mesaverde formation. Dip, 34° S., 50° E.

The bed was measured and sampled at one point in the mine on October 11, 1912, by E. T. Hancock, as shown below:

Section of coal bed in Shafer mine.

Laboratory No.	14909	
Roof, brown shale.	*Ft.*	*in.*
Coal	9	6
Coal, impure	0	6
Coal	3	9
Shale, black, carbonaceous (3 inches).		
Floor, brown shale.		
Thickness of bed	13	9
Thickness of coal sampled	13	9

The sample was taken in the mine 189 feet northeast of the mine mouth.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 415, p. 170.

CRAIG. WALKER MINE.

Sample.—Subbituminous coal; Yampa field; analysis No. 12400 (p. 33).

Mine.—Walker; sec. 17, T. 6 N., R. 90 W.; about 3 miles southeast of Craig, not on any railroad.

Coal bed.—Unnamed. Cretaceous age, Mesaverde formation. The coal is 8 feet thick and very free from foreign matter. The bed was sampled at one point in the mine by A. J. Hazelwood on June 20, 1911.

The sample was cut from the face of the main entry, 300 feet west of the opening.

Notes.—The Walker mine is an old country bank and had been in operation 20 to 30 years. At the time of sampling the coal was run out of the mine in cars and dumped into wagons. The coal was used entirely for domestic purposes. The coal was screened in the mine by means of forks and the fine coal was left in the gob. It was estimated that there was about 1,000 tons of slack in the worked-over parts of the mine. About one-fifth of the coal is slack. The output averaged approximately 20 tons per month. There was 1,000 acres of coal tributary to this opening.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 297, 1906, p. 62.

MONTEZUMA COUNTY.

CORTEZ. CORTEZ MINE.

Sample.—Bituminous coal; Ute Mountain-Mancos field; analysis No. 12785 (p. 33).

Mine.—Cortez; NW. ¼ sec. 23, T. 36 N., R. 16 W.; one-half mile west of Cortez.

Coal bed.—The lowest bed in the Dakota formation; Cretaceous age. Dip 6°, northwest. In many places this bed is about 2 feet thick and exceeds that thickness only locally. The coal is extremely irregular in character, and sections taken only a few feet apart may not be alike. In many places the roof is sandstone, at other places it is shale, the shale is only a few inches, scarcely ever over 1 foot thick. Sandstone lenses interbedded with the coal are not uncommon.

The bed was measured and sampled at one point in the mine on October 20, 1911. by F. M. Handy and M. A. Pishel, as shown below:

Section of coal bed in Cortez mine.

Laboratory No.	12785	
Roof, sandstone.	*Ft.*	*in.*
Coal, bony	0	6
Clay	[a] 0	6
Shale	[a] 0	11½
Bone	[a] 0	4
Coal, bony	[a] 0	7½
Coal	0	2
Bone	[a] 0	2½
Coal	0	11
Bone	[a] 0	6
Floor, shale.		
Thickness of bed	4	8½
Thickness of coal sampled	1	7

[a] Not included in sample.

Notes.—The mine is small and is worked intermittently for local trade. No one was at the mine at the time the sample was taken. There were no screens at the mine; the entire output being loaded as run-of-mine coal. The sample is probably slightly weathered.

CORTEZ. HAMILTON PROSPECT.

Sample.—Bituminous coal; Ute Mountain-Mancos field; analysis No. 12686 (p. 33).

Mine.—Hamilton prospect; in SE. ¼ sec. 3, T. 35 N., R. 18 W., 16 miles southwest of Cortez.

Coal bed.—Unnamed bed. Cretaceous age, Dakota formation. The bed lies nearly horizontal, in many places is about 2 feet thick and exceeds that thickness only locally. The coal is extremely irregular in character and sections taken only a few feet apart may not be alike. The roof is sandstone; at places the sandstone is replaced by shale, which is only a few inches, scarcely ever over 1 foot thick. It is not uncommon to find sandstone lenses interbedded with the coal.

The bed was measured and sampled at one point in the mine on September 17, 1911, by M. A. Pishel, as shown below:

Section of coal bed in Hamilton prospect, about 16 miles southwest of Cortez.

Laboratory No.	12686	
	Ft.	*in.*
Coal	0	6
Shale	[a]0	4
Bone	[a]0	7
Coal, bony	0	7
Bone	[a]0	1
Coal	0	6
Bone	[a]0	1
Thickness of bed	2	8
Thickness of coal sampled	1	7

[a] Not included in sample.

The sample was taken near the surface in an open cut.

Notes.—This prospect was within a mile of an igneous sheet and it is probable that this sheet extended over the bed only a short distance above the coal. The coal at the prospect had a semimetallic luster resembling semianthracite, whereas the coal of this bed in the neighborhood of Cortez has the appearance of typical bituminous coal. It is probable that this phenomenon is due to the proximity of this prospect to the igneous sheet referred to above.

CORTEZ. JACKSON MINE.

Sample.—Bituminous coal; Ute Mountain-Mancos field; analyses Nos. 16472, 16473, 16474, and 16475 (p. 34).

Mine.—Jackson, a drift mine in the SW. ¼ NE. ¼ sec. 33, T. 35 N., R. 16 W., 10 miles southeast of Cortez, in the Mesa Verde National Park. There are no railroad connections.

Coal bed.—Lower bed of the Mesaverde formation, possibly the Spencer bed; Cretaceous age. Average thickness, 2 feet 8 inches; dip, 2° southwest; cleat, northeast and southwest. Faults, rolls, and horsebacks occur frequently. The roof is a hard blue shale; above the shale is a sandstone cap rock. Floor is hard smooth shale. Cover at points of sampling, 30 feet.

The bed was measured and sampled at three points in the mine by J. C. Roberts on February 13, 1913, as described below:

Sections of coal bed in Jackson mine.

Section	A		B		C	
Laboratory No.	16472		16473		16474	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	10	2	7	2	7
Shale and sandstone	..	..	..	..	[a]1	8
Coal	..	..	..	..	[a]1	0
Floor, shale.						
Thickness of bed	2	10	2	7	5	3
Thickness of coal sampled	2	10	2	7	2	7

[a] Not included in sample.

Section A (sample 16472) was measured at the face of room 4, off the north entry, 200 feet from the mine mouth.

Section B (sample 16473) was measured at the face of the main entry, 170 feet north of the mine mouth.

Section C (sample 16474) was measured at the face of the south entry, 95 feet from the mine mouth.

A composite sample was made by mixing samples 16472, 16473, and 16474. The results of an ultimate analysis of this sample are given under laboratory No. 16475.

Notes.—The mine is worked on the room-and-pillar system. At the time of sampling the development consisted of a pair of entries driven slightly north of east with four rooms turned. The coal was undercut by hand and shot down with black blasting powder. The coal was screened over a "grizzley" with wood bars 2 inches by 4 inches by 10 feet long spaced three-fourths inch apart. The coal was used entirely for domestic purposes. The daily output of the mine was 1 ton. Sixty acres remained to be mined from this opening.

CORTEZ. MOWRY MINE.

Sample.—Bituminous (coking) coal; Durango field; analyses Nos. 12586 and 16479 (p. 34).

Mine.—Mowry, a drift mine, 1½ miles southeast of Cortez, no railroad connection.

Coal bed.—Unnamed bed. Cretaceous age, Dakota formation. The bed varies greatly in thickness and completely pinches out a quarter of a mile from the mine. The bed averages about 2 feet thick and exceeds that thickness only locally. Dip, 3° northwest. There is a layer of bony coal in the lower part which varies from 2 to 6 inches. No faults, rolls, or horsebacks have been encountered. The roof is a smooth sandstone; at places the sandstone is replaced by shale. The floor is shale and a smooth sandy clay. Particles from the roof and floor did not mix with the coal in mining. Cover at point of sampling, about 70 feet.

The bed was measured and sampled at one point in the mine by M. A. Pishel on August 28, 1911, and at one point by J. C. Roberts on February 14, 1913, as described below:

Sections of coal bed in Mowry mine.

Section	A		B	
Laboratory No.	12586		16479	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	2	1	9
Bone	[a]0	6	[a]0	5
Floor, clay and shale.				
Thickness of bed	2	8	2	2
Thickness of coal sampled	2	2	1	9

[a] Not included in sample.

Section A (sample 12586) was taken near the face, 75 feet from the mine mouth. Fine streaks of bony coal were interlaminated with the coal at this point.

Section B (sample 16479) was taken in the main entry 100 feet from the mine mouth.

Notes.—At the time of sampling the coal was blasted off the solid with black blasting powder. The coal was marketed for domestic purposes and was forked and dumped directly into the wagons for delivery. The yearly output was about 150 tons.

CORTEZ. TODD MINE.

Sample.—Bituminous coal; Durango field; analyses Nos. 16476, 16477, and 16478 (p. 34).

Mine.—Todd, a drift mine, in sec. 25, T. 35 N., R. 16 W., in the Mesa Verde National Park, about 7 miles from Cortez and 19 miles from the Rio Grande Southern Railroad.

Coal bed.—Lowest bed of the Mesaverde formation, Cretaceous age. Thickness, 2 feet 6 inches to 3 feet 6 inches. The bed has a thin persistent parting of shale one fourth inch to three-fourths inch thick near the middle. Roof, shale of poor quality; above the shale is a sandstone cap rock. Floor, hard smooth underclay. Particles of the roof and floor did not mix with the coal in loading. Cover at points of sampling, 80 to 100 feet.

The bed was measured and sampled at two points in the mine by J. C. Roberts on February 12, 1913, as described below:

Sections of coal bed in the Todd mine.

Section	A		B	
Laboratory No	16476		16477	
Roof, "draw slate".	*Ft.*	*In.*	*Ft.*	*In.*
Coal	1	½	1	3½
Shale	0	½	0	½
Coal	1	9	1	8
Floor, clay.				
Thickness of bed	2	10	3	0
Thickness of coal sampled	2	10	3	0

Section A (sample 16476) was measured at the face of room 9.

Section B (sample 16477) was measured at the face of room 10.

A composite sample was made by combining face samples 16476 and 16477. The results of an ultimate analysis of this sample are given under laboratory No. 16478.

Notes.—The mine is worked by the room-and-pillar system. At the time of sampling the coal was undercut and mined by hand, no explosives being used. The undercuttings were thrown into the gob. The coal was screened over bars 12 feet long with one-half-inch openings and picked as it was being loaded. The daily output was 4 tons, which was hauled from the mine in wagons. There were about 80 acres to be mined from this opening.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 75, 467.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 316, p. 389.

DOLORES. PROSPECT.

Sample.—Bituminous coal; Ute Mountain-Mancos field; analysis No. 12551 (p. 35).

Mine.—Unnamed prospect in the NE. ¼ sec. 29, T. 36 N., R. 15 W., 11 miles south of Dolores.

Coal bed.—Unnamed bed. Cretaceous age, Dakota formation. Dip, 2° northeast. In many places this bed is about 2 feet thick and exceeds that thickness only locally. The coal is extremely irregular in character, and sections taken only a few feet apart may not be alike. The roof is sandstone, which in places is replaced by shale; the shale is only a few inches, scarcely ever over 1 foot thick. Sandstone lenses interbedded in the coal are not uncommon.

The bed was measured and sampled by M. A. Pishel on August 18, 1911, as shown below:

Section of coal bed in prospect entry, 11 miles south of Dolores.

Laboratory No	12551	
Roof, sandy shale.	*Ft.*	*In.*
Coal	0	3½
Shale	[a]0	4½
Coal	0	4
Bone	[a]0	2
Coal, slightly bony	0	10
Bone	[a]0	4
Coal, bony	[a]0	8
Bone	[a]0	1
Coal	0	9
Bone	[a]0	2
Coal	0	4
Bone (1½ feet).		
Floor, not stated.		
Thickness of bed	4	4
Thickness of coal sampled	2	6½

[a] Not included in sample.

Note.—The prospect apparently had not been worked for some time before the sample was taken, so that the sample is probably somewhat weathered. It was taken near the face of the entry, 20 feet from the mouth.

MANCOS. HALLER MINE.

Sample.—Bituminous coal; Durango field; analysis No. 12504 (p. 35).

Mine.—Haller; a drift mine in NE. ¼ sec. 30, T. 37 N., R. 13 W., 6 miles north of Mancos.

Coal bed.—Unnamed bed. Cretaceous age, Dakota formation. Dip, 2°. In many places this bed is about 2 feet thick and exceeds that thickness only locally. The coal is extremely irregular in character, being interlaminated with bone, shale, and sandstone lenses, and sections taken only a few feet apart may not be alike. In many places the roof is sandstone, at others it is shale; the latter is only a few inches, scarcely ever over 1 foot thick.

The bed was measured and sampled at one point in the mine on July 31, 1911, by M. A. Pishel, as shown below:

Section of coal bed in Haller mine.

Laboratory No.	12504	
Roof, shale.	*Ft.*	*in.*
Coal	0	7
Bone	[a] 0	6
Coal	0	3
Bone	[a] 1	2
Coal	0	5
Bone	[a] 0	5
Coal	0	6
Floor, shale.		
Thickness of bed	3	10
Thickness of coal sampled	1	9

[a] Not included in sample.

The sample was taken in the entry, about 50 feet from the mine mouth.

Note.—The mine had not been worked for at least six months previous to the time this sample was taken, so the sample is probably somewhat weathered.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 75,467.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 316, p. 387.

MANCOS. PROSPECT.

Sample.—Bituminous coal; Ute Mountain-Mancos field; analysis No. 12444 (p. 35).

Location.—An unnamed prospect in NE. ¼ sec. 21, T. 36 N., R. 12 W., 8 miles northeast of Mancos.

Coal bed.—Unnamed bed. Cretaceous age, Dakota formation. Dip 6½° south. In many places this bed is about 2 feet thick, and exceeds that thickness only locally. The coal is extremely irregular in character, being irregularly interlaminated with bone, shale, and sandstone lenses, and sections taken only a few feet apart may not be alike. In many places sandstone forms the roof, at others it is shale; the latter is a few inches to 1 foot thick.

The bed was measured and sampled July 16, 1911, by M. A. Pishel, as shown below:

Section of coal bed in prospect entry 8 miles northeast of Mancos.

Laboratory No.	12444	
Roof, sandstone, good.	*Ft.*	*in.*
Shale	[a] 0	2
Coal	0	6
Coal, bony	0	3
Bone	[a] 0	2
Coal	0	2
Shale	[a] 0	2½
Coal, slightly bony	0	3
Floor, shale.		
Thickness of bed	1	8½
Thickness of coal sampled	1	2

[a] Not included in sample.

Note.—This sample was taken 20 feet from mouth of entry. The coal was somewhat weathered, as apparently coal had not been taken out of the prospect for at least one year. This bed is not known to be thicker at any place within 3 or 4 miles of this prospect.

OURAY COUNTY.

Ridgway. Lou Creek Mine.

Sample.—Bituminous coal; Tongue Mesa field; analysis No. 12651 (p. 35).

Mine.—Lou Creek, a drift mine in NE. ¼ NE. ¼ sec. 22, T. 46 N., R. 7 W., 10 miles northeast of Ridgway.

Coal bed.—Lou Creek. Cretaceous age, Mesaverde formation. The character of the bed outside the mine is not known, and neither top nor bottom was exposed. The entry was run in on the coal, which appeared to be at least 20 feet thick, but this thickness may be due in part to crushing.

The bed was measured and sampled by W. T. Lee on September 12, 1911.

The sample was collected from the lower 6 feet of the bed as exposed in the mine, 600 feet from the mouth of the mine. Very little coal was mined; it was used for local purposes.

RIO BLANCO COUNTY.

Meeker. Black Diamond Mine.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 12776 (p. 35).

Mine.—Black Diamond; in sec. 15, T. 1 N., R. 94 W.; 1½ miles northwest of Meeker, 47 miles north of the Denver & Rio Grande Railroad.

Coal bed.—Lord. Cretaceous age, Mesaverde formation. Thickness at least 14 feet.

The bed was measured and sampled at one point in the mine on October 18, 1911, by E. T. Hancock, as shown below:

Section of coal bed in Black Diamond mine.

Laboratory No.	12776	
Sandstone.	*Ft.*	*in.*
Coal	3	10
Coal, streaked with shale	0	4
Coal	2	3
Thickness of bench mined	6	5
Thickness of coal sampled	6	5

There was coal below this section. The sample was taken in the mine 174 feet northeast of the entrance.

For analyses and descriptions of other samples of coal from this mine, see Bull. 22, Bureau of Mines, 1913, pp. 77, 471–472.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 415, 1910, p. 153.

Meeker. Cornrike Mine.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 12695 (p. 35).

Mine.—Cornrike mine; SW. ¼ sec. 10, T. 2 N., R. 93 W.; 10 miles northeast of Meeker; 54 miles north of Rifle, which is on the Denver & Rio Grande Railroad.

Coal bed.—No name. Cretaceous age, Mesaverde formation. Dip 20° S., 27° E. Total thickness measured outside of mine, 21 feet 7 inches.

The bed was measured and sampled at one point in the mine by E. T. Hancock, on October 5, 1911.

The sample was taken in the mine, 30 feet northeast of the mine mouth, in a 7-foot 6-inch bench of clean coal. There was coal above and below the bench.

Notes.—For a description of the coal beds in this township, see U. S. Geol. Survey Bull. 415, 1910, pp. 160–162.

Meeker. Fairfield Mine.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 12518 (p. 35).

Mine.—Fairfield; SW. ¼ sec. 28, T. 1 N., R. 94 W.; 2½ miles west of Meeker and 45 miles north of the Denver & Rio Grande Railroad.

Coal bed.—No name. Cretaceous age, Mesaverde formation. Dip, 42° N., 67° W.

The bed was measured and sampled at one point in the mine by E. T. Hancock on August 12, 1911, as shown below:

Section of coal bed in Fairfield mine.

Laboratory No	12518	
Roof, coal (not mined).	*Ft.*	*in.*
Coal	6	0
Bone	[a] 0	4
Coal	0	4
Floor, carbonaceous shale.		
Thickness of coal mined	6	8
Thickness of coal sampled	6	4

[a] Excluded from sample.

The sample was taken in the mine, 300 feet northeast of the mine mouth.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 316, 1910, p. 143.

Meeker. Meeker Mine.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 12426 (p. 35).

Mine.—Meeker NW. ¼ sec. 22, T. 1 N., R. 94 W., three-fourths mile northwest of Meeker and 46 miles north of the Denver & Rio Grande Railroad.

Coal bed.—Old Pollard. Cretaceous age, Mesaverde formation. Dip, 20° NW.

The bed was measured and sampled at one point in the mine by E. T. Hancock on July 15, 1911.

The sample was taken in the mine about 500 feet northeast of the mine mouth and represents 6 feet 6 inches of coal. There was sandstone above the coal and brown shale below it.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 316, 1910, p. 151.

Meeker. Montgomery Mine.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 12777 (p. 35).

Mine.—Montgomery; SE. ¼ NW. ¼ sec. 29, T. 1 N., R. 94 W.; 3 miles west of Meeker, on the main stage road, and about 42 miles north of the Denver & Rio Grande Railroad.

Coal bed.—No name. Cretaceous age, Mesaverde formation. Thickness, 7 feet 6 inches. Dip, 60° NW.

The bed was measured and sampled by E. T. Hancock on October 18, 1911.

The sample was taken in the mine 474 feet northeast of the mine mouth, in 7 feet 6 inches of coal. There was sandstone above the coal and a brown shale below it.

For a description of the coal beds of Meeker Township see U. S. Geol. Survey Bull. 316, 1910, pp. 141–160.

Meeker. Sulphur Creek Mine.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 12773 (p. 35).

Mine.—Sulphur Creek, in SE. ¼ sec. 3, T. 1 N., R. 94 W., on Sulphur Creek, 2½ miles north of Meeker and 49 miles north of the Denver & Rio Grande Railroad. No railroad connections.

Coal bed.—No name. Cretaceous age; Mesaverde formation.

The bed was measured and sampled at one point in the mine by E. T. Hancock on October 17, 1911, as shown below:

Section of coal bed in Sulphur Creek mine.

Laboratory No.	[illegible]	
Roof, coal (not mined).	*Ft.*	*in.*
Coal	1	4
Sandstone, shaly	0	⅜
Coal	0	1
Sandstone, shaly	ᵃ0	½
Coal	1	6
Shale, carbonaceous	ᵃ0	⅜
Coal	2	4½
Floor, shale.		
Thickness of bench mined	5	9
Thickness of coal sampled	5	7⅜

ᵃ Not included in sample.

The sample was taken in the mine, 245 feet north of the mine mouth.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 77, 78, 473.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 415, 1910, p. 155.

MEEKER. WESSON MINE.

Sample.—Bituminous coal; Danforth Hills field; analysis No. 12705 (p. 35).

Mine.—Wesson, on the west side of Coal Creek, in sec. 30, T. 2 N., R. 92 W., 12 miles northeast of Meeker and 55 miles north of the Denver & Rio Grande Railroad.

Coal bed.—No name. Cretaceous age, Mesaverde formation. Thickness, about 22 feet 3½ inches. Dip, 60° SW.

The bed was measured and sampled at one point in the mine by E. T. Hancock on October 6, 1911, as shown below:

Section of coal bed in the Wesson mine.

Laboratory No.	12705	
Coal (not mined).	*Ft.*	*in.*
Coal	2	1
Coal, shaly	0	1
Coal	11	0
Shale, carbonaceous	ᵃ0	1
Coal	2	4
Sandstone	ᵃ0	½
Coal	2	8
Coal (not mined).		
Thickness of coal mined	18	3½
Thickness of coal sampled	18	2

ᵃ Not included in sample.

Sample 12705 was taken in the mine, 258 feet northwest of the mine mouth.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 415, 1910, p. 164.

IDAHO.

BOISE COUNTY.

HORSESHOE BEND. HENRY MINE.

Sample.—Subbituminous coal; Horseshoe Bend field; analyses Nos. 12391 and 12703 (p. 35).

Mine.—Henry, a slope mine in NW. ¼ sec. 3, T. 6 N., R. 2 E., at Horseshoe Bend, about 20 miles north of Boise.

Coal bed.—No name. Tertiary age, Payette formation. Thickness irregular, average 18 to 20 inches; dip about 50° west. Roof, black shale; floor, clay.

The bed was sampled and measured at one point in the mine by C. T. Kirk and C. F. Bowen, on June 22 and at one point by C. F. Bowen on October 8, 1911, as shown below:

Section of coal bed in Henry mine.

Laboratory No	12703	
	Ft.	*in.*
Roof, shale.		
Coal	1	6
Clay	[a]0	4
Bone	[a]0	2
Coal	[a]0	4
Bone	[a]0	3
Clay	[a]0	2
Floor, sandstone.		
Thickness of bed	2	9
Thickness of coal sampled	1	6

[a] Not included in sample.

Notes.—Sample 12703 was taken in the Jensen level, 140 feet from the mouth of the slope and about 175 feet below the surface. It represents freshly mined coal.

Sample 12391 was taken about 60 feet from the mouth of the slope and represents 2 feet of coal. As the face had been exposed to the atmosphere for about a year the coal was perhaps more or less weathered.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 531, 1911, p. 249.

CASSIA COUNTY.

OAKLEY. WORTHINGTON MINE.

Sample.—Lignite; Goose Creek district; analysis No. 12643 (p. 36).

Mine.—Worthington; a slope mine SE. ¼ sec. 26 (unsurveyed), T. 16 S., R. 20 E., on Goose Creek, about 22 miles southwest of Oakley.

Lignite bed.—Worthington. Tertiary age, Payette (?) formation. Dip, about 10° east. The bed was measured and sampled at one point in the mine, by C. F. Bowen on September 19, 1911, as shown below:

Section of lignite bed in Worthington mine.

Laboratory No	12643	
Roof, clay.	*Ft.*	*in.*
Lignite	1	8
Clay	[a]0	1½
Lignite	2	4
Thickness of bed	4	1½
Thickness of coal sampled	4	0

[a] Not included in sample.

The sample was taken in the slope about 200 feet from its mouth.

Notes.—This is the most important bed in the Goose Creek district. At the time of sampling in 1911 the mine had been idle for more than a year. For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 531 1913, p. 258.

FREMONT COUNTY.

HADEN. BROWN BEAR MINE.

Sample.—Bituminous coal; Teton Basin field; analysis No. 15115 (p. 36).

Mine.—Brown Bear; in sec. 25, T. 5 N., R. 43 E.; Horseshoe Creek district, about 10 miles southwest of Haden.

Coal bed.—Not named. Cretaceous age; formation not yet determined.

The bed was measured and sampled at one point in the mine by E. G. Woodruff on September 28, 1912, as shown below:

Section of coal bed in Brown Bear mine.

Laboratory No.	15115	
Roof, shale.	*Ft.*	*in.*
Coal	3	11
Shale	[a]0	3
Coal	1	1
Shale.		
Thickness of bed	5	3
Thickness of coal sampled	5	0

[a] Not included in sample.

Sample 15115 was taken at the end of the north entry, 950 feet from the portal, where mining had been done recently and where the coal was unweathered.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 541, 1914.

HADEN. HORSESHOE MINE.

Sample.—Bituminous coal; Teton Basin field; analysis No. 15116 (p. 36).

Mine.—Horseshoe; in sec. 6, T. 4 N., R. 44 E.; Horseshoe Creek district, about 10 miles southwest of Haden.

Coal bed.—Not named. Cretaceous age; formation not yet determined.

The bed was measured and sampled at one point in the mine by E. G. Woodruff on September 28, 1912, as shown below:

Section of coal bed in Horseshoe mine.

Laboratory No.	15116	
Roof, shale.	*Ft.*	*in.*
Coal	1	11
Sandstone	[a]0	10
Coal	3	4
Coal, very impure	[a]1	9
Coal	3	3
Floor, shale.		
Thickness of bed	11	1
Thickness of coal sampled	8	6

[a] Not included in sample.

Notes.—This sample was taken in an abandoned mine about 200 feet from the portal at a point where the bed is under 60 feet of cover. The mine was dry. The face had been exposed for more than a year and was cleaned before sampling. The coal was probably slightly weathered.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 541, 1914.

ILLINOIS.

MADISON COUNTY.

COLLINSVILLE. CANTINE NO. 3 MINE.

Sample.—Bituminous coal; Illinois field; analyses Nos. 10956, 10957, 10958, and 10959 (p. 36).

Mine.—Cantine No. 3, a shaft mine in the Central Illinois district, 1 mile east of Collinsville, on the Vandalia Railroad.

Coal bed.—Herrin coal (Belleville, No. 6) of the United States Geological Survey. Carboniferous age, Carbondale formation. Average thickness, 7 feet 3 inches. The f is a gray shale, above the shale is a limestone cap rock. The floor is a smooth, fire clay.

The bed was measured and sampled at three points in the mine by P. M. Riefkin on September 23, 1910, as described below:

Sections of coal bed in Cantine No. 3 mine.

Section	A	B	C
Laboratory No	10956	10957	10958
Roof, gray shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	1 4	1 1½	1 6½
"Sulphur"	0 ¼	0 ⅛	0 ¼
Coal	1 4¾	1 2	0 8
"Sulphur"	[a]0 ½	[a]0 1	0 ⅛
Coal	0 5½	0 5¼	0 5
"Sulphur"	[a]0 ½	[a]0 ¼	[a]0 ½
Coal	0 8½	0 8	1 0
Mother coal	0 ¼	[a]0 1	0 ¼
Coal	1 3½	1 2¼	1 6¼
"Sulphur"	[a]0 1¼	[a]0 1	[a]0 ⅝
Coal	0 9½	0 5¾	0 5¼
Hard blue band	[a]0 1	[a]0 1¼	[a]0 1
Bottom coal	1 5	1 5½	1 10
Floor, fire clay.			
Thickness of bed	7 8½	6 10⅞	7 7¾
Thickness of coal sampled	7 5¼	6 6⅜	7 5⅝

[a] Not included in sample.

Section A (sample 10956) was measured on the rib, 10 feet from the face of west entry 10 off the north heading, 3,200 feet northwest of the shaft.

Section B (sample 10957) was measured at the face of the first stub on east entry 8 off the north heading, 4,200 feet north of the shaft.

Section C (sample 10958) was measured on the rib 8 feet from the face of east entry 7, off the south heading, 2,500 feet southeast of the shaft.

A composite sample was made by combining face samples 10956, 10957, and 10958. The results of an ultimate analysis of this sample are shown under laboratory No. 10959.

Notes.—The mine is opened by a shaft 165 feet deep. At the time of sampling the coal was undercut with punching machines and broken down with black powder. The tipple was equipped with shaker screens to prepare the coal for various commercial and domestic sizes. There were four loading tracks with a capacity of 40 loaded and 20 empty cars.

MONTGOMERY COUNTY.

PANAMA. PANAMA No. 1 MINE.

Sample.—Bituminous coal; Illinois field; analyses Nos. 11352, 11353, and 11354 (p. 37).

Mine.—Panama No. 1, a shaft mine in Gresham Township, one-fourth of a mile north of Panama, on the Toledo, St. Louis & Western Railroad.

Coal bed.—Herrin coal (Belleville, No. 6) of the United States Geological Survey. Carboniferous age, Carbondale formation. Thickness, 6 feet 6 inches to 7 feet 6 inches. Roof, limestone; floor, clay. The bed was measured and sampled at two points in the mine by R. Y. Williams, on November 23, 1910, as shown below:

Sections of coal bed in Panama No. 1 mine.

Section	A	B
Laboratory No	11352	11353
Roof, limestone.	*Ft. in.*	*Ft. in.*
Coal	1 11	1 7
"Sulphur"	[a] Knife edge.	[a]0 ½
Coal	0 4½	0 9½
"Sulphur"	[a]0 ¼	[a]0 ¼
Coal	0 6	0 5¾

[a] Not included in sample.

Sections of coal bed in [illegible] No. [illegible] mine—Continued.

	Ft.	in.	Ft.	in.
Roof, limestone, continued.				
"Sulphur"	a0	[illegible]	a0	[illegible]
Coal	[illegible]	2	....	
Mother coal	[illegible]	[illegible]	....	
Coal	[illegible]	6	1	4
"Sulphur"	a0	[illegible]	a Knife edge.	
Coal	[illegible]	[illegible]	0	[illegible]
"Sulphur" [illegible]	a0	[illegible]	a0	[illegible]
Coal	[illegible]	11	0	11[illegible]
"Sulphur"	a0	[illegible]	a0	[illegible]
Coal	[illegible]	[illegible]	0	2
"Sulphur"	a0	[illegible]	a0	[illegible]
Coal	[illegible]	2	0	1
"Sulphur"	a0	[illegible]	a0	1
Coal	[illegible]	2	0	4
Floor, clay.				
Thickness of bed	[illegible]	[illegible]	6	[illegible]
Thickness of coal sampled	[illegible]	3	6	[illegible]

a Not included in sample.

Section A (sample 11352) was measured at the face of room 1, third south stub off the third westward entry, about 2,000 feet from the shaft.

Section B (sample 11353), was measured at the face of room 4, third north stub off west entry 6, off north entry, 2,000 feet from the shaft.

A composite sample was made by combining face samples 11352 and 11353. The results of an ultimate analysis of this sample are given under laboratory No. 11354.

Notes. The mine is opened by a shaft about 375 feet deep. The coal is mined by both the room-and-pillar and the panel systems. Entry pillars are left to protect the entries. At the time of sampling the mine was equipped to produce 2,500 tons of coal per 8-hour day.

SALINE COUNTY.

HARRISBURG, O'GARA NO. 9 MINE.

Sample. Bituminous coal; Illinois field; analysis Nos. 12794 and 12795 (p. 37).

Mine. O'Gara No. 9, a shaft mine in the Saline County district, 1 mile south of Harrisburg, on the Big Four Railroad.

Coal bed. No. 5 of the Illinois Geological Survey. Carboniferous age, Carbondale formation. Average thickness, 6 feet; dip 3 per cent northeast. Cleat, northeast and southwest. Occasional dikes are encountered. Roof, a blue shale; 2 to 14 inches of this shale comes down with the coal in mining; floor, a hard clay. Cover at points of sampling, 150 to 240 feet.

The bed was measured and sampled at two points in the mine by H. I. Smith on August 27, 1911, as described below:

Sections of coal bed in O'Gara No. 9 mine.

Section	A		B	
Laboratory No.	12794		12795	
Roof, blue shale.	*Ft.*	*in.*	*Ft.*	*in.*
Coal, bright	0	7½	0	6
Mother coal or "sulphur"	a0	1½	..	..
Coal, bright	0	6	..	..
"Sulphur"	a0	¼	a0	¼
Coal, laminated with dirt bands	1	3	..	..
Bone or "sulphur"	0	¼	..	..
Coal, bright	4	10½	6	1
Floor, hard clay.				
Thickness of bed	7	5	6	7¼
Thickness of coal sampled	7	3	6	7

a Not included in sample.

Section A (sample 12794) was measured at the face of west entry 3, off the main south entry, between rooms 18 and 19, about 3,000 feet from the shaft.

Section B (sample 12795) was measured at the face of the second crosscut in room 11, off west entry 3, off the main south entry.

Notes.—The mine is opened by a shaft 152 feet deep. The coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by electric chain cutting machines and shot down with C, F, FF, and FFF black blasting powder. No explosives were used for brushing the roof or floor. None of the coal was shipped as run-of-mine. The screening equipment consisted of a double-decked bar screen 21 feet long by 7 feet wide, the upper screen having openings 2 inches by 2½ inches and the lower screen openings 1¼ inches square. Pickers were employed on the car in loading. There were three loading tracks with a capacity of 40 empty and 60 loaded cars. The daily output averaged 2,500 tons; the capacity was 3,100 tons.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 90, 507.

For results of tests of coal from this mine see mention of specific tests as follows—Steaming tests: U. S. Geol. Survey Bull. 332, p. 119; Bureau of Mines Bull. 23, pp. 61, 159; briquetting tests, U. S. Geol. Survey Bull. 332, p. 119.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 316, 1907, p. 130.

VERMILION COUNTY.

WESTVILLE. LITTLE VERMILION MINE.

Sample.—Bituminous coal; Illinois field; analysis No. 14682 (p. 37).

Mine.—Little Vermilion, a mine in the Grape Creek district, sec. 19, T. 18 N., R. 11 W., 2 miles south of Westville.

Coal bed.—No. 6 of the Illinois Geological Survey. Carboniferous age, Carbondale formation.

Sample 14682 represents a car of run-of-mine coal used in combustion test (test No. 336) at the Bureau of Mines testing plant at Pittsburgh, Pa. The sample was taken by E. R. Linkenhoker while the car was being unloaded.

INDIANA.

SULLIVAN COUNTY.

DUGGER. VANDALIA NO. 10 MINE.

Sample.—Bituminous coal; bituminous coal field; analyses Nos. 10960 and 10961 (p. 37).

Mine.—Vandalia No. 10, 1½ miles southwest of Dugger, on the Vandalia Railroad.

Coal bed.—No. 4 of the Indiana Geological Survey. Carboniferous age, Allegheny formation. Average thickness, about 5 feet 6 inches. Roof, a gray shale 20 feet thick; above the shale is a sandstone cap rock. Floor, clay 6 to 10 feet thick; below the clay is a sandstone. The bed was measured and sampled at two points in the mine by R. Y. Williams on September 21, 1910, as described below:

Sections of coal bed in Vandalia No. 10 mine.

Section	A		B	
Laboratory No.	10960		10961	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*
Rash	..	..	[a]0	½
Coal, hard and bright	1	5	2	8
Bone and shale	..	..	[a]0	2
Natural charcoal	[a]0	½	..	..
Coal, hard and bright	0	5½	0	3
"Sulphur" and bone	..	..	[a]0	½
Natural charcoal	0	½	..	..
Coal, hard and bright	1	¾	1	11½
Bottom coal	..	..	0	2
Shale parting	[a]0	2	..	..
Coal, hard and bright	2	3	..	..
Floor, clay.				
Thickness of bed	5	5¼	5	3½
Thickness of coal sampled	5	2¾	5	½

[a] Not included in sample.

Section A (sample 10960) was measured at the face of room 2, off east entry 6 off north entry 2, off the main east entry.

Section B (sample 10961) was measured at the face of room 12, off east entry 6 off north entry 2, off the main east entry.

Note.—At the time of sampling the output was 1,600 tons a day.

WARRICK COUNTY.

ELBERFELD. ELBERFELD MINE.

Sample.—Bituminous coal; bituminous coal field; analysis No. 16578 (p. 37).

Mine.—Elberfeld, a shaft mine 1 mile south of Elberfeld station on the E. & I. siding.

Coal bed.—No. 5 of the Indiana Geological Survey. Carboniferous age, Allegheny formation. Average thickness, 4 feet 6 inches; dip southwest, in places as much as 5°. The coal has a cleat, but no faults or horsebacks. There are no persistent partings, but kidney "sulphur" and "sulphur" flakes occur at intervals. The roof is a hard black shale which does not come down in mining, overlain by a softer shale. The floor is a hard fire clay which mixed slightly with the coal in loading. Cover at point of sampling, 185 feet.

The bed was measured and sampled at one point in the mine by J. J. Rutledge and H. D. Mason, jr., on February 6, 1913, as described below:

Section of coal bed in Elberfeld mine.

Section	A	
Laboratory No	16578	
Roof, hard black shale.	*Ft.*	*in.*
Coal	1	0
"Steel" band	0	¼
Coal	0	8
"Steel" band	0	¼
Coal	2	4
Floor, hard fire clay.		
Thickness of bed	4	½
Thickness of coal sampled	4	½

Section A (sample 16578) was measured in the new manway off the main west entry, 200 feet north of the shaft bottom.

Notes.—The mine is opened by a shaft 185 feet deep, and the coal is mined by the room-and-pillar, double-entry system. At the time of sampling the coal was undercut by hand and shot down with C and F black blasting powder. Seventy-five per cent of the coal was shipped as run-of-mine. The coal was hoisted on a self-dumping cage to a wooden tipple. The tipple had shaking screens 40 feet long by 5 feet wide with 2½-inch holes. Pickers were employed on the cars while loading. There were three loading tracks, with a capacity of 25 empty and 25 loaded cars. The average daily output was 250 tons, the capacity 300 tons. About 50 acres remained to be mined from the present opening.

KANSAS.

CRAWFORD COUNTY.

FRANKLIN. WESTERN NO. 16 MINE.

Sample.—Bituminous coal; Kansas field; analysis No. 17032 (p. 37).

Mine.—Western No. 16; one-fourth of a mile west of Franklin, on the Missouri Pacific Railway and the Atchison, Topeka & Santa Fe Railway.

Coal bed.—Weir-Pittsburg. Carboniferous age, Cherokee shale. Average thickness, 2 feet 10 inches; dip, northwest. The coal is very clean except for thin streaks of pyrite near the middle of the coal bed. Rolls, clay veins, horsebacks, and slips are numerous and a source of much added expense in mining. Roof, bluish shale; floor, underclay, which at times heaves. Cover at point of sampling, about 220 feet.

The bed was measured and sampled at one point in the mine by C. S. Stevenson on April 16, 1913.

Sample 17032 was taken at a point in the mine 2,000 feet southwest of the shaft, and represents 2 feet 11 inches of clean coal. There was shale above the coal and clay below it.

Notes.—The mine is opened by a shaft 219 feet deep. The coal is mined by the double-entry, room-and-pillar system. At the time of sampling the coal was shot off the solid and gave trouble in sticking to the roof. In the haulageways the top was brushed to a height of 2 feet, but in the air course the top was not brushed. The coal was principally marketed for railroad purposes. The output was about 700 tons a day.

FULLER. SHERIDAN NO. 2 MINE.

Sample.—Bituminous coal; Kansas field; analyses Nos. 11181, 11182, 11183, and 11184 (p. 38).

Mine.—Sheridan No. 2, a shaft mine in sec. 12, T. 29 N., R. 25 E., in the southwest corner of the town of Fuller, on the Kansas City Southern Railway.

Coal bed.—Wier-Pittsburg. Carboniferous age, Cherokee shale. Average thickness, 3 feet; bed horizontal. Roof, dark gray shale 10 to 12 feet thick; floor, hard shale.

The bed was measured and sampled at three points in the mine by R. D. Killian on November 12, 1910, as described below:

Sections of coal bed in Sheridan No. 2 mine.

Section	A		B		C	
Laboratory No.	11181		11182		11183	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	0	1	0	1	0
"Sulphur" band	[a]0	½	[a]0	½	[a]0	½
Coal	1	4	1	4	1	4
"Sulphur" band	[a]0	½	[a]0	½	[a]0	½
Coal	0	7	0	7	0	7
Floor, shale.						
Thickness of bed	3	0	3	0	3	0
Thickness of coal sampled	2	11	2	11	2	11

[a] Excluded from sample.

Section A (sample 11181) was measured at the face, 2,500 feet southwest of the shaft.

Section B (sample 11182) was measured at the face, 2,500 feet northeast of the shaft.

Section C (sample 11183) was measured at the face, 2,500 feet northwest of the shaft.

A composite sample was made by combining face samples 11181, 11182, and 11183. The results of an ultimate analysis of this sample are shown under laboratory No. 11184.

Notes.—At the time of sampling the output was 375 to 400 tons a day.

YALE. WESTERN NO. 13 MINE.

Sample.—Bituminous coal; Kansas field; analyses Nos. 11209, 11210, 11211, and 11212 (p. 38).

Mine.—Western No. 13, a shaft mine in sec. 26, T. 30 N., R. 25 E., three-fourths of a mile northwest of Yale, on the Missouri Pacific Railroad.

Coal bed.—Wier-Pittsburg (?). Carboniferous age, Cherokee shale. Average thickness, 3 feet; practically horizontal. Roof, dark gray shale 30 feet thick; floor, soft shale. Cover at points of sampling, 87 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on November 14, 1910, as described below:

Sections of coal bed in Western No. 13 mine.

Section	A	B	C
Laboratory No	11209	11210	11211
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	1 8	1 8	1 8
"Sulphur" band	[a]0 ⅓	[a]0 ⅓	[a]0 ⅓
Coal	1 3⅔	1 3⅔	1 3⅔
Floor, shale.			
Thickness of bed	3 0	3 0	3 0
Thickness of coal sampled	2 11⅔	2 11⅔	2 11⅔

[a] Not included in sample.

Section A (sample 11209) was measured at the face, 2,600 feet north of the shaft.

Section B (sample 11210) was measured at the face, 2,800 feet southeast of the shaft.

Section C (sample 11211) was measured at the face, 2,800 feet southwest of the shaft.

A composite sample was made by combining face samples 11209, 11210, and 11211. The results of an ultimate analysis of this sample are shown under laboratory No. 11212.

Notes.—The mine is opened by a shaft about 90 feet deep. At the time of sampling the output was 500 tons a day.

LEAVENWORTH COUNTY.

LANSING. PENITENTIARY MINE.

Sample.—Bituminous coal; Kansas field; analyses Nos. 12841, 12842, 12843, and 12844 (pp. 38, 39).

Mine.—Penitentiary; sec. 19, T.9S., R. 23E.; Leavenworth district; on Missouri Pacific, Atchison, Topeka & Santa Fe, and Union Pacific railroads.

Coal bed.—Bevier. Carboniferous age, Pennsylvanian series, Cherokee shale. Roof, chiefly firm, dark drab shale; floor, thin underclay on limestone. Thickness, regular, average 22 inches. Cover at points of sampling, 720 feet.

The bed was measured and sampled at three points in the mine by M. Albertson on September 15, 1911.

Sample 12841 was taken 1,100 feet south and 1,400 feet east of the shaft in 22 inches of coal.

Sample 12842 was taken 4,400 feet east and 500 feet north of the shaft in 22 inches of coal.

Sample 12843 was taken 2,300 feet east and 2,600 feet north of the shaft in 22 inches of coal.

A composite sample was made by mixing face samples 12841, 12842, and 12843. The results of the ultimate analysis of this sample are shown under laboratory No. 12844.

LEAVENWORTH. NO. 1 MINE.

Sample.—Bituminous coal; Kansas field; analyses Nos. 12849, 12850, 12851, and 12852 (p. 39).

Mine.—No. 1; Leavenworth district, at Leavenworth; sec. 36, T. 8 S., R. 22 E.; on the Missouri Pacific Railway.

Coal bed.—Bevier. Carboniferous age, Pennsylvanian series, Cherokee shale. Roof, chiefly firm, dark drab shale; floor, thin underclay on limestone. Thickness, regular, average 22 inches. Cover at points of sampling, 720 feet.

The bed was measured and sampled at two points in the mine by M. Albertson on September 16, 1911.

Sample 12849 was taken 3,200 feet north and 560 feet west of the shaft in 21 inches of coal.

Sample 12850 was taken 160 feet west and 3,100 feet south of the shaft in 21 inches of coal.

Sample 12851 was taken 110 feet east and 3,310 feet north of the shaft in 22 inches of coal.

A composite sample was made by mixing face samples 12849, 12850, and 12851. The results of an ultimate analysis of this sample are shown under laboratory No. 12852.

Leavenworth. No. 3 Mine.

Sample.—Bituminous coal; Kansas field; analyses Nos. 12845, 12846, 12847, and 12848 (p. 39).

Mine.—No. 3; Leavenworth district, at Leavenworth; sec. 25, T. 8 S., R. 22 E.; on Missouri Pacific Railway.

Coal bed.—Bevier. Carboniferous age, Pennsylvanian series, Cherokee shale. Roof, chiefly firm, dark drab shale; floor, thin underclay on limestone. Thickness, regular, average 22 inches. Cover, 720 feet. The bed was measured and sampled at two points in the mine by M. Albertson on September 18, 1911.

Sample 12845 was taken 3,400 feet southeast of the shaft in 22 inches of coal.

Sample 12846 was taken 3,800 feet southeast of the shaft in 22 inches of coal.

Sample 12847 was taken 3,350 feet southeast of the shaft in 22 inches of coal.

A composite sample was made by mixing face samples 12845, 12846, and 12847. The results of an ultimate analysis of this sample are shown under laboratory No. 12848.

KENTUCKY.

LETCHER COUNTY.

Flat Gap, Va. Local Mine.

Sample.—Bituminous coal; eastern Kentucky field; analysis No. 15172 (p. 39).

Mine.—A local drift mine, 1½ miles south of Flat Gap, Va., 10 miles from the nearest railroad.

Coal bed.—Lower Standiford. Carboniferous age, Wise formation. Thickness uniform, nearly flat. Roof, shale; floor, clay. Cover at points of sampling, 25 feet.

The bed was measured and sampled at one point in the mine by Charles Butts on November 1, 1912.

Sample 15172 was taken in the entry about 15 feet from the mine mouth, in 3 feet 2 inches of coal, all of which was included in the sample. The roof at this point was shale and the floor was clay.

Notes.—Bright, firm coal, sold for domestic use.

Flat Gap, Va. J. H. Mullin Mine.

Sample.—Bituminous coal; eastern Kentucky field; analysis No. 15173 (p. 39).

Mine.—J. H. Mullin, a local mine 3½ miles southwest of Flat Gap, Va., and 10 miles from the nearest railroad.

Coal bed.—Lower Bolling. Carboniferous age, Wise formation. The bed was measured and sampled at one point in the mine by Charles Butts on November 1, 1912, as described below:

Section of coal bed in J. H. Mullin mine.

Laboratory No	15173	
	Ft.	*in.*
Coal	2	3
Clay	[a]0	2
Coal	1	6
Clay	[a]0	4
Coal	0	4
Thickness of bed	4	7
Thickness of coal sampled	4	1

[a] Not included in sample.

The above section was measured in the main entry, 40 feet from the mine mouth.

JENKINS. CONSOLIDATION NO. 204 MINE.

Sample.—Bituminous coal; eastern Kentucky field; analyses Nos. 14904 and 14905 (p. 39).

Mine.—Consolidation No. 204, a drift mine at Jenkins, on the Baltimore & Ohio Railroad.

Coal bed.—Upper Elkhorn. Carboniferous age, Pottsville group. Thickness, uniform, flat. Roof, shale; floor, clay.

The bed was measured and sampled at two points in the mine by Charles Butts on October 12, 1912, as described below:

Sections of coal bed in Consolidation No. 204 mine.

Section	A		B	
Laboratory No.	14904		14905	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	3	7	4	0
Clay	[a]0	3	[a]0	5
Coal	3	8½	4	0
Floor, clay.				
Thickness of bed	7	6½	8	5
Thickness of coal sampled	7	3½	8	0

[a] Not included in sample.

Section A (sample 14904) was measured at the face of the main heading, 1,700 feet from the mine mouth.

Section B (sample 14905) was measured at the face of the east heading, 1,700 feet from mine mouth.

Notes.—The clay parting near the middle of the bed is soft and friable and is utilized as a mining bench. Most of the bed is coal of medium hardness and brightness, but the lower 18 inches includes a considerable proportion of tough hard splint coal. A large part of the output was being shipped to Michigan, where it was utilized in by-product ovens.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 348, p. 37.

JENKINS. LOCAL MINE.

Sample.—Bituminous coal; eastern Kentucky field; analyses Nos. 14970 and 14971 (p. 40).

Mine.—A local drift mine, 5 miles northeast of Jenkins, near the Baltimore & Ohio Railroad.

Coal bed.—Lower Elkhorn; Carboniferous age, Pottsville group. Thickness uniform, flat. Roof, sandstone; floor, clay.

The bed was measured and sampled by Charles Butts, October 16, 1912, as described below:

Section of coal bed in mine 5 miles north of Jenkins.

Laboratory No.	14970 14971	
Roof, sandstone.	*Ft.*	*in.*
Coal	[a]0	8
Coal, laminated	[b]1	0
Coal	[a]1	4½
Floor, clay.		
Thickness of bed	3	½

[a] Included in sample 14970.

[b] Included in sample 14971.

The section was measured at the face of the entry, 50 feet from the mouth of the mine.

Notes.—The laminated bench of soft coal is 1 foot thick and is high in impurities. The output is used for local, domestic, and steam purposes.

MUHLENBERG COUNTY.

CENTRAL CITY. CENTRAL MINE.

Sample.—Bituminous coal; western Kentucky field; analyses Nos. 13257, 13258, 13259, and 13260 (p. 40).

Mine.—Central, a shaft mine one-eighth of a mile south of the depot at Central City, on the Owensburg-Russelville branch of the Louisville & Nashville Railroad and on the Louisville branch of the Illinois Central Railroad.

Coal bed.—No. 9 of the Kentucky Geological Survey. Carboniferous age, Pottsville group. Thickness, 4 feet 9 inches to 6 feet. The bed dips north about 15 feet per mile. The coal contains thin streaks of "sulphur" and some "sulphur" balls. The roof is a black shale 2 to 4 feet thick and is of good quality. The floor is a clay which weathers when exposed to air. Upon exposure for a year it weathers to an average depth of 6 inches and this feature is utilized by driving the narrow work about one year in advance of turning the rooms. Cover at points of sampling, about 170 feet.

The bed was measured and sampled at three points in the mine by C. S. Stevenson on January 22 and 23, 1912.

Sample 13257 was taken at the face of the main south entry, and represents 5 feet 6 inches of clear coal.

Sample 13258 was taken in room 20, off the main south blind entry, and represents 5 feet 6 inches of clear coal.

Sample 13259 was taken in room 8, off sixth south entry, off the main west entry, and represents 5 feet 6 inches of clear coal.

A composite sample was made by mixing face samples 13257, 13258, and 13259. The results of an ultimate analysis of this sample are given under laboratory No. 13260.

Notes.—The mine is opened by a shaft 170 feet deep and is worked on the room-and-pillar system. At the time of sampling, all the coal was undercut with picks to one-half the depth of the drill hole and broken down with F and FF black blasting powder. Most of the output was used for domestic purposes, a small amount being sold for transportation purposes.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 106, 542.

For results of tests of coal from this mine see mention of specific tests as follows—Steaming tests: Bull. 13, Bureau of Mines, pp. 137, 274; coking tests: U. S. Geol. Survey Bull. 336, 1908, pp. 23, 30, 39; cupola tests of coke: U. S. Geol. Survey Bull. 336, pp. 50, 53, 56, 59, 62.

CLEATON. BEVIER MINE.

Sample.—Bituminous coal, western Kentucky field; analyses Nos. 15339, 15340, and 15341 (p. 40).

Mine.—Bevier, a shaft mine at Cleaton, opposite the railroad station, on the Louisville & Nashville Railroad.

Coal bed.—No. 9 of the Kentucky Geological Survey. Carboniferous age, Pottsville group. Average thickness, 5 feet 4 inches. Dip, 1° southwest. The coal bed has no persistent partings, but contains discontinuous "sulphur" flakes and bands. The roof is a firm, hard, black shale about 6 inches thick; above the shale is a main cap rock. The floor is a hard, smooth fire clay, which crumbles on exposure to the air. The material from the roof and floor did not mix with the coal in mining. Cover at points of sampling, about 130 feet.

The bed was measured and sampled at three points in the mine by H. D. Mason, jr., on December 23, 1912.

Sample 15339 was taken at the face of room 15, off the eighth north air course, 4,100 feet from the shaft. The sample represents 5 feet 3 inches of coal.

Sample 15340 was taken at the face of room 21, off seventh north entry, 3,800 feet from the shaft. The sample represents 5 feet 6 inches of coal.

Sample 15341 was taken at the face of eighth south entry, 4,500 feet from the shaft. The sample represents 5 feet 3 inches of coal.

At all three places some thin "sulphur" bands and flakes were present and are included in the samples.

Notes.—The mine is opened by a shaft 69 feet deep and the coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by compressed-air machines and broken down with FF black blasting powder. Machine cuttings were loaded with the coal. The tipple had a perforated screen 12 feet long and 5 feet wide, with 1 to 4 inch openings. About 38 per cent of the coal going to the screen passed through the 1-inch holes. Thirty per cent of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. The lumps loaded were large and of good appearance. There were three loading tracks, with a capacity of 22 empty and 22 loaded cars. The output was about 750 tons a day, all from advance work, but the intent was to increase it to 1,000 tons. There was approximately 900 acres of unmined coal tributary to this tipple.

GRAHAM. SKIBO MINE.

Sample.—Bituminous coal; western Kentucky field; analyses Nos. 16674 and 16675 (p. 41).

Mine.—Skibo, a slope mine, 2 miles north of Graham, on a spur of the Illinois Central Railroad.

Coal bed.—No. 9 of the Kentucky Geological Survey. Carboniferous age, Pottsville group. Average thickness, 4 feet 10 inches; dip, 1 per cent southwest. Only one fault has been encountered; it extends miles. There are no persistent partings in the coal, although "sulphur" occurs in flakes and bands. The roof is a gray shale, 18 inches thick, which comes down with the coal in places; above the shale is a cap rock. The floor is a hard smooth fire clay. Particles from the roof and floor did not mix with the coal in mining. Cover at points of sampling, about 150 feet.

The bed was measured and sampled at two points in the mine by H. D. Mason, jr., on May 5, 1913.

Sample 16674 was cut from the face of west entry 2, off north entry 1, 4,000 feet north of the mine mouth. The bed at this point was 4 feet 10 inches thick. The sample represents the entire section.

Sample 16675 was cut from the face of room 2, off seventh east entry, 3,600 feet north of the mine mouth. The bed at this point was 4 feet 9 inches thick. The sample represents the entire thickness of the bed.

Notes.—The coal is mined by the room-and-pillar double-entry system. At the time of sampling the coal was undercut with chain machines and broken down with FF black blasting powder. The cuttings were loaded out with the coal. About 40 per cent of the coal was shipped as run-of-mine. The tipple had shaking screens 25 feet long and 6 feet wide, with holes 1 to 2½ inches in diameter. About 22 per cent of the coal going to the screens passed through the screens. Pickers were employed on the cars in loading. The lumps were large and of good appearance. There were three loading tracks, with a capacity of 50 empty and 50 loaded cars. The daily output was 922 tons, with a capacity of 1,000 tons. The greater part of the coal was from advance workings, although some of it was from pillars. There were approximately 2,000 acres of unmined coal tributary to this opening.

OHIO COUNTY.

McHENRY. McHENRY MINE.

Sample.—Bituminous coal; western Kentucky field; analyses Nos. 15102 and 15103 (p. 41).

Mine.—McHenry, a slope mine near McHenry, on the Illinois Central Railroad.

Coal bed.—No. 9 of the Kentucky Geological Survey. Carboniferous age, Pottsville group. Thickness, fairly uniform, average 4 feet 6 inches. Roof, dark shale, overlain by a blue sandstone. Floor, hard smooth underclay. Particles of the floor got mixed with the coal in mining.

The bed was measured and sampled at two points in the mine by H. D. Mason, jr., on November 13, 1912.

Sample 15102 was taken at the face of room 4, off south entry 3; 9,000 feet from the mine mouth. The sample includes the entire section, 4 feet 6 inches, except a "sulphur" band 26 inches above the bottom.

Sample 15103 was taken at the face of room 1, off north entry 1; 8,500 feet from the mine mouth. The sample includes the entire section, 4 feet 6 inches, except a "sulphur" band 26 inches above the bottom.

Notes.—The mine was not being operated at the time these samples were taken. In mining, the coal was undercut by hand in the coal and broken down with FF black blasting powder. About 50 per cent of the coal was shipped as run-of-mine. Pickers were employed on the cars. The lumps were large and made a good appearance on the cars. The track had a capacity of 40 loaded cars and 30 empty cars. The average daily production had been 700 tons. There was approximately 1,000 acres of unmined coal tributary to this opening.

PIKE COUNTY.

HELLIER. EDGEWATER MINE.

Sample.—Bituminous coal; Russell Fork field; analysis No. 12004 (p. 41).

Mine.—Edgewater, 1 mile southeast of Hellier post office.

Coal bed.—Upper Elkhorn; Carboniferous age; Kanawha (?) formation. Thickness, 3 feet 6 inches. A sample of run-of-mine coal from this mine was taken on March 28, 1911, by C. H. Wegemann, from three loaded railroad cars, the coal having been mined the previous day.

MISSOURI.[a]

ADAIR COUNTY.

KIRKSVILLE. STAR MINE.

Sample.—Bituminous coal; Novinger field; analyses Nos. 14799 and 14800 (p. 41).

Mine.—Star, a shaft mine in the Kirksville district, in sec. 8, T. 63 N., R. 15 W., one-half mile west of Kirksville.

Coal bed.—Bevier. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 14 to 36 inches. Cover, 290 feet. The bed was measured and sampled at two points in the mine by M. Albertson on September 28, 1912.

Sample 14799 was taken 30 feet south of the shaft and represented 17½ inches of coal.

Sample 14880 was taken 12 feet northeast of the shaft and represented 20 inches of coal.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 114, 562.

---

[a] The coal fields of Missouri are described in detail in The Coal Deposits of Missouri, by Henry Hinds, Missouri Bureau of Geology and Mines, vol. 11, ser. 2, 1913.

AUDRAIN COUNTY.

MARTINSBURG. NO. 1 MINE.

Sample.—Bituminous coal; Vandalia field; analyses Nos. 11483, 11484, 11485, and 11478 (p. 41).

Mine.—No. 1, a shaft mine in sec. 14, T. 50 N., R. 7 W., one-fourth mile west of Martinsburg, with connections to the Wabash Railroad and the Chicago & Alton Railroad.

Coal bed.—Mulky. Carboniferous age, Pennsylvanian series, Cherokee shale. Average thickness, 2 feet 6 inches; bed practically horizontal. Roof, calcareous shale. Floor, fire clay, 10 inches thick, underlain by limestone. Cover at points of sampling, 135 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 19, 1910.

Sample 11483 was taken at the long-wall face, 600 feet south of the shaft.

Sample 11484 was taken at the long-wall face, 600 feet southwest of the shaft.

Sample 11485 was taken at the face, 800 feet southwest of the shaft.

At each of the points sampled the coal bed was 2½ feet thick, overlain by 8 inches of "draw slate," above which was the shale roof. The floor was clay.

A composite sample was made by combining face samples 11483, 11484, and 11485. The results of an ultimate analysis of this sample are given under laboratory No. 11478.

Notes.—The shaft is 135 feet deep; the long-wall system of mining is employed. At the time of sampling the output was 40 tons a day.

BARTON COUNTY.

MINDENMINES. NO. 17 MINE.

Sample.—Bituminous coal; Minden field; analyses Nos. 11185, 11186, 11187, and 11188 (p. 42).

Mine.—No. 17, a shaft mine in sec. 30 T. 32 N., R. 33 W., 2 miles northwest of Mindenmines post office, on the Missouri Pacific Railway.

Coal bed.—Wier-Pittsburg Lower. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 2 feet 10 inches to 3 feet; bed, horizontal. Roof, shale 20 feet thick, overlain by sandstone 2½ feet thick; floor, soft shale. Cover, 60 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on November 11, 1910.

Sample 11185 was taken at the face, 1,000 feet northeast of the shaft, where there was 2 feet 10 inches of clean coal.

Sample 11186 was taken at the face, 1,000 feet southeast of the shaft, where there was 2 feet 10 inches of clean coal.

Sample 11187 was taken at the face, 1,500 feet northwest of the shaft, where there was 2 feet 10 inches of clean coal.

There was shale above and below the coal at each of the points sampled. The samples represent the entire thickness of the bed.

A composite sample was made from face samples 11185, 11186, and 11187. The results of an ultimate analysis of this sample are given under laboratory No. 11188.

Notes.—The shaft is 64 feet deep. The coal is mined by the room-and-pillar system. At the time of sampling the coal was shot off the solid. The mine was comparatively new and was equipped to produce 400 tons a day.

MINDENMINES. PULLEN NO. 1 MINE.

Sample.—Bituminous coal; Minden field; analyses Nos. 11177, 11178, 11179, and 11180 (p. 42).

Mine.—Pullen No. 1, a shaft mine in sec. 28, T. 32 N, R. 33 W., 1 mile northeast of Mindenmines post office, on a branch of the Missouri Pacific Railway.

Coal bed.—Wier-Pittsburg Lower. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 2 feet 6 inches. Bed practically horizontal. Roof, shale 5 to 10 feet thick; floor, soft clay. Cover at points of sampling, about 40 feet.

The bed was measured and sampled at three points in Pullen No. 1 mine by R. D. Killian on November 10, 1910.

Sample 11177 was taken at the south face, 600 feet from the shaft, and represents 2 feet 6 inches of coal. There was a "sulphur" band one-sixteenth inch thick near the middle of the bed.

Sample 11178 was taken at the west face, 400 feet from the shaft, and represents 2 feet 7 inches of coal. There was a soft-coal ("mother coal") parting about one-sixteenth inch thick near the middle of the bed.

Sample 11179 was taken at the northeast face, 600 feet from the shaft, and represents 2 feet 6 inches of coal. There was a "sulphur" band one-sixteenth inch thick near the middle of the bed.

A composite sample was made by combining face samples 11177, 11178, and 11179. The results of an ultimate analysis of this sample are given under laboratory No. 11180.

Notes.—The shaft is 40 feet deep. The coal is mined by the room-and-pillar system. At the time of sampling the coal was blasted off the solid. The output was 60 tons a day.

BATES COUNTY.

AMSTERDAM. No. 1 MINE.

Sample.—Bituminous coal; Foster field; analyses Nos. 11306, 11307, 11308, and 11309 (pp. 42, 43).

Mine.—No. 1, in sec. 20, T. 41 N., R. 33 W., in the southern part of the village of Amsterdam, on the Kansas City Southern Railway.

Coal bed.—Mulberry. Carboniferous age, Pennsylvanian series, Pleasonton shale. Thickness variable, average about 2 feet; bed horizontal. Roof, calcareous shale, overlain by limestone; floor, hard clay, underlain by limestone. Cover, 90 to 100 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 3, 1910.

Sample 11306 was taken at the face, 400 feet east of the shaft.

Sample 11307 was taken at the face, 400 feet south of the shaft.

Sample 11308 was taken 400 feet southeast of the shaft.

The lower 1 foot of coal in each section contained bands of sulphur and bone.

Each sample represents 2 feet 6 inches of coal, the thickness of the bed.

A composite sample was made by combining face samples 11306, 11307, and 11308. The results of an ultimate analysis of the sample are given under laboratory No. 11309.

Notes.—The shaft is 100 feet deep. The mine is worked by the room-and-pillar system. At the time of sampling the output was about 25 tons a day.

HUME. No. 1 MINE.

Sample.—Bituminous coal; Foster field; analyses Nos. 11226, 11227, 11228, and 11229 (p. 43).

Mine.—No. 1, in sec. 4, T. 38 N., R. 33 W., Howard Township, 4 miles east of Hume and 10 miles west of Rich Hill, on a branch of the St. Louis & San Francisco Railroad.

Coal bed.—Mulberry. Carboniferous age, Pennsylvanian series, Pleasonton shale. Thickness, 2 feet 6 inches to 3 feet. The bed lies horizontal. Roof, "draw slate" 6 inches thick, overlain by shale 15 feet thick; floor, soft clay. Cover, about 50 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on November 21, 1910.

Sample 11226 was taken at the face, 900 feet northwest of the shaft.

Sample 11227 was taken at the face, 1,100 feet west of the shaft.

Sample 11228 was taken at the face, 700 feet southwest of the shaft.

At each of the points sampled the coal bed was 2½ feet thick.

A composite sample was made by combining face samples 11226, 11227, and 11228. The results of an ultimate analysis of this sample are given under laboratory No. 11229.

Notes.—The shaft is 35 feet deep. The coal is mined by the room-and-pillar system. At the time of sampling the capacity was 50 tons a day.

NEW HOME. NEW HOME NO. 1 MINE.

Sample.—Bituminous coal; Rich Hill field; analyses Nos. 11222, 11223, 11224, and 11225 (p. 43).

Mine.—No. 1, a shaft mine in sec. 30, T. 39 N., R. 32 W., at New Home. It has railroad facilities for shipment over the St. Louis & San Francisco, the Missouri Pacific, and the Kansas City Southern railroads.

Coal bed.—Lower Rich Hill. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 5 feet. The bed is horizontal in general but more or less undulating. Roof, limestone, 1 foot thick, overlain by shale about 4 feet thick; floor, clay, 6 feet thick. Cover, 260 to 280 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on November 22, 1910.

Sample 11222 was taken at the face, 200 feet northeast of the shaft, and represents 5 feet of clean coal.

Sample 11223 was measured at the face, 150 feet southeast of the shaft, and represents 5 feet of clean coal.

Sample 11224 was measured at the face, 200 feet south of the shaft, and represents 5 feet of clean coal.

At each of the points sampled the entire thickness of the bed was included.

A composite sample was made by combining face samples 11222, 11223, and 11224. The results of an ultimate analysis of this sample are given under laboratory No. 11225.

Notes.—The shaft is 278 feet deep. The coal is mined by the room-and-pillar system. The output at the time of sampling was about 50 tons a day.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 116, 567.

RICH HILL. FLEMING PIT NO. 1.

Samples.—Bituminous coal; Rich Hill field; analyses Nos. 11197, 11198, 11199, and 11200 (p. 43).

Mine.—Fleming Pit No. 1, an open-pit mine in sec. 36, T. 39 N., R. 32 W., 2 miles northwest of Rich Hill, on a branch of the Missouri Pacific Railway.

Coal bed.—Lower Rich Hill. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 5 feet. The bed lies nearly horizontal. Roof, shale, 4 feet thick; floor, hard clay. Cover, 13 feet.

The bed was measured and sampled at three points in the pit by R. D. Killian on November 19, 1910.

Sample 11197 was taken at the face on the north side of the pit.

Sample 11198 was taken at the face on the east side of the pit.

Sample 11199 was taken at the face on the south side of the pit.

At each of the points sampled the bed was 5 feet thick, and had a 2-inch "sulphur" band 1 foot 10 inches from the bottom. Each sample represents 4 feet 10 inches of coal, the 2-inch band being excluded.

A composite sample was made by combining face samples 11197, 11198, and 11199. The results of an ultimate analysis of this sample are shown under laboratory No. 11200.

Notes.—At the time of sampling Fleming Pit No. 1 was one of the largest strippings near Rich Hill. The daily output was about 50 tons.

RICH HILL. RITCHIE PITS NOS. 1 AND 2.

Sample.—Bituminous coal; Rich Hill field; analyses Nos. 11193, 11194, 11195, and 11196 (p. 44).

Mine.—Ritchie Pits No. 1 and No. 2, in sec. 17, T. 38 N., R. 31 W., 2 miles south of Rich Hill, on a branch of the Missouri Pacific Railroad.

Coal bed.—Lower Rich Hill. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, about 5 feet. The bed is slightly inclined. Roof, black shale, 4 feet thick; floor, clay. Cover, 10 to 16 feet.

The bed was measured and sampled at two points in No. 1 pit and at one point in No. 2 pit by R. D. Killian on November 18, 1910.

Sample 11193 was taken at the face on the north side of open pit No. 1.

Sample 11194 was taken at the face on the south side of open pit No. 1.

At each of the above points the bed measured 4 feet 11 inches. There was a "sulphur" band 1 inch thick at the bottom and a 2-inch band of "lignite" about 1 foot 8 inches from the bottom. These parts were excluded from the samples.

A composite sample was made by combining face samples 11193 and 11194. The results of an ultimate analysis of this sample are given under laboratory No. 11195.

Sample 11196 was cut from the face of the south side of open pit No. 2. The bed measured 2 feet at this point, all of which is represented in the sample.

Notes.—At pit No. 1 a slope had been opened and underground work was being carried on. The output was 30 tons a day.

BOONE COUNTY.

COLUMBIA. NO. 1 AND NO. 2 MINES.

Samples.—Bituminous coal; Bevier field; analyses Nos. 11475, 11476, and 11477 (p. 44).

Mines.—No. 1 and No. 2, shaft mines in the Columbia district, in sec. 4, T. 48 N., R. 12 W., 3½ miles northeast of Columbia, a shipping station on the Wabash Railroad.

Coal bed.—Bevier (?). Carboniferous age, Pennsylvanian series, Cherokee shale. Average thickness, 3 feet; slight dip to southeast. Roof, blue calcareous shale, 3 feet thick; floor, fire clay. Cover, 100 to 110 feet.

The bed was measured and sampled at two points in No. 1 mine and at one point in No. 2 mine by R. D. Killian on December 17, 1910.

Sample 11475 was taken at the face, 50 feet west of the shaft, mine No. 2.

Sample 11476 was taken at the face, 110 feet north of the shaft, mine No. 1.

Sample 11477 was taken 50 feet west of the shaft, mine No. 1.

Each sample represents 3 feet of coal, the thickness of the bed.

Notes.—The shafts are 110 feet deep. The coal is mined by the room-and-pillar system. At the time of sampling the output was 30 tons a day. The coal was used for local consumption.

COLUMBIA. PRATHER NO. 1 MINE.

Sample.—Bituminous coal; Bevier field; analyses Nos. 11479, 11480, 11481, and 11482 (p. 44).

Mine.—Prather No. 1, a shaft mine in sec. 11, T. 49 N., R. 12 W., 4½ miles north of Columbia, which is the nearest shipping point on the Wabash Railroad.

Coal bed.—Bevier. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 40 to 42 inches. The bed is more or less undulating with a slight dip to the southeast. Roof, black shale; floor, hard fire clay. Cover, 35 to 65 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 17, 1910.

Sample 11479 was taken at the face, 600 feet southwest of the shaft.

Sample 11480 was taken at the face, 600 feet west of the shaft.

Sample 11481 was taken at the face, 800 feet east of the shaft.

At each of the points sampled the bed was 3 feet 6 inches thick, all of which was included in the sample.

There is an 18-inch bed of coal 30 feet above the bed mined and an 18-inch bed of coal about 10 feet below it.

A composite sample was made from face samples 11479, 11480, and 11481. The results of an ultimate analysis of this sample are given under laboratory No. 11482.

Notes.—The shaft is 36 feet deep. The coal is mined by the room-and-pillar method. At the time of sampling the capacity was 35 tons a day; the coal was used for local purposes.

CALLAWAY COUNTY.

FULTON. NO. 1 MINE.

Sample.—Bituminous coal; Bevier field; analyses Nos. 11501, 11502, 11503, and 11504 (p. 45).

Mine.—No. 1, a shaft mine in sec. 18, T. 47 N., R. 9 W., 2 miles southwest of Fulton, on a spur of the Chicago & Alton Railroad.

Coal bed.—Bevier. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 2 feet 6 inches. The bed lies practically horizontal. Roof, soft shale mixed with clay, about 12 inches thick, above the shale is a limestone cap rock 14 feet thick; floor, hard fire clay. Cover, 90 to 110 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 20, 1910.

Sample 11501 was taken at the face, 1,000 feet east of the shaft.

Sample 11502 was taken at the face, 600 feet northeast of the shaft.

Sample 11503 was taken at the face, 600 feet southwest of the shaft.

Each sample represents 2 feet 6 inches of coal, the thickness of the bed.

A composite sample was made by combining face samples 11501, 11502, and 11503. The results of an ultimate analysis of this sample are given under laboratory No. 11504.

Notes.—The mine is opened by a shaft 92 feet deep and is worked by the longwall system. At the time of sampling the output was 40 tons a day; most of the coal was used locally.

HARRISON COUNTY.

CAINESVILLE. CAINESVILLE MINE.

Sample.—Bituminous coal; Cainesville field; analyses Nos. 12679, 12680, and 12681 (p. 45).

Mine.—Cainesville, a shaft mine in sec. 13, T. 65 N., R. 26 W., at Cainesville, on the Chicago, Burlington & Quincy Railroad.

Coal bed.—Cainesville. Carboniferous age, Pennsylvanian series, Cherokee shale. Roof, drab to black shale; floor, hard sandy clay. Thickness, 3 feet 8 inches to 5 feet; average, 4 feet. Cover, 480 feet.

The bed was measured and sampled at three points in the mine by Henry Hinds on September 26, 1911.

Sample 12679 was taken in the main west air course, 600 feet west and 50 feet north he shaft, and represents 3 feet 10½ inches of coal.

Sample 12680 was taken in south entry 2, off the main east entry, 150 feet east and 350 feet south of the shaft, and represents 3 feet 9½ inches of coal.

Sample 12681 was taken in south entry 2, off the main west entry, 400 feet southwest of the shaft, and represents 3 feet 9½ inches of coal. Each sample represents the entire thickness of the bed.

MELBOURNE. TRENTON NO. 1 MINE.

Sample.—Bituminous coal; analyses Nos. 11374, 11375, 11376, and 11377 (p. 45).

Mine.—Trenton No. 1, a shaft mine in sec. 25, T. 62 N., R. 26 W., one-fourth mile east of Melbourne, near the county line, and on the Quincy, Omaha & Kansas City Railroad.

Coal bed.—Lexington. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 3 feet. The bed lies practically horizontal. Roof, shale 8 inches thick, overlain by calcareous shale 2 feet thick. Floor, hard clay. Cover, 138 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 7, 1910.

Sample 11374 was taken at the face, 90 feet south of the shaft.

Sample 11375 was taken at the face, 85 feet northeast of the shaft.

Sample 11376 was taken at the face, 30 feet north of the shaft.

At each of the points sampled the bed was 3 feet thick. There was a 2-inch band of clay and "sulphur" 1 foot below the top of the coal. This was excluded in sampling the coal. There was shale above the coal. Below the coal was soft clay about 3 inches thick, underlain by hard clay.

A composite sample was made by combining face samples 11374, 11375, and 11376. The results of an ultimate analysis of this sample are given under laboratory No. 11377.

Notes.—The mine is opened by a shaft about 140 feet deep and is worked by the longwall system. At the time of sampling the output was 25 tons a day.

HENRY COUNTY.

CALHOUN. PARKS NO. 1 MINE.

Sample.—Bituminous coal; Lewis field; analyses Nos. 11314, 11315, 11316, and 11317 (p. 46).

Mine.—Parks No. 1, a drift mine in sec. 25, T. 34 N., R. 26 W., 2½ miles west of Calhoun, on the Missouri, Kansas & Texas Railway.

Coal bed.—Tebo. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 2 feet 8 inches. The bed lies horizontal. Roof, shale 3½ feet thick, overlain by limestone 20 inches thick. Floor, soft fire clay. Cover, about 15 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on November 30, 1910.

Sample 11314 was taken at the face, 700 feet southeast of the mine mouth.

Sample 11315 was taken at the face, 700 feet southwest of the mine mouth.

Sample 11316 was taken at the face, 800 feet west of the mine mouth.

At each of the points sampled the bed measured 2 feet 8 inches. There was a "sulphur" band 1 inch thick about 1 foot 4 inches from the top of the coal. This was excluded in sampling.

A composite sample was made by combining face samples 11314, 11315, and 11316. The results of an ultimate analysis of this sample are given under laboratory No. 11317.

Notes.—The coal is mined by the longwall system. At the time of sampling the output was 35 tons a day.

CLINTON. LANE No. 1 MINE.

Sample.—Bituminous coal; Lewis field; analyses Nos. 11248, 11249, 11250, and 11251 (p. 46).

Mine.—Lane No. 1, a slope mine in sec. 28, T. 42 N., R. 26 W., 3½ miles northwest of Clinton, with connections to the St. Louis & San Francisco Railroad.

Coal bed.—Tebo. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 2 feet 6 inches. The bed dips slightly. Roof, calcareous shale; floor, clay. Cover, 18 to 20 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on November 25, 1910.

Sample 11248 was taken at the face, 210 feet northwest of the mine mouth, and represents 2 feet 6 inches of clean coal.

Sample 11249 was taken at the face, 300 feet northeast of the mine mouth, and represents 2 feet 6 inches of clean coal.

Sample 11250 was taken at the face, 230 feet north of the mine mouth, and represents 2 feet 6 inches of clean coal.

At each of the points sampled the entire thickness of the bed was included.

A composite sample was made from face samples 11248, 11249, and 11250. The results of an ultimate analysis of this sample are given under laboratory No. 11251.

Notes.—The mine is worked by the longwall system. At the time of sampling the daily output was 20 tons.

CLINTON. NEIL No. 1 MINE.

Sample.—Bituminous coal; analyses Nos. 11302, 11303, 11304, and 11305 (p. 46).

Mine.—Neil No. 1, a shaft mine in sec. 34, T. 42 N., R. 26 W., 1 mile north of Clinton, on the St. Louis & San Francisco Railroad.

Coal bed.—Not correlated. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 2 feet 6 inches. The bed lies practically horizontal. Roof, siliceous limestone 6 feet thick; floor, clay. Cover at points of sampling, 25 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 1, 1910.

Sample 11302 was taken at the face, 200 feet southwest of the shaft.

Sample 11303 was taken at the face, 100 feet northwest of the shaft.

Sample 11304 was taken 75 feet east of the shaft.

At each of the points sampled the bed was 2 feet 6 inches thick, with a 2-inch "sulphur" band 10 inches from the top. This was excluded from the samples, which represent 2 feet 4 inches of coal.

A composite sample was made by combining face samples 11302, 11303, and 11304. The results of an ultimate analysis of this sample are given under laboratory No. 11305.

Notes.—The mine is opened by a shaft about 30 feet deep and is worked by the longwall method. At the time of sampling the output was 12 tons a day. The coal was used for local purposes.

CLINTON. PHARIS No. 1 MINE.

Sample.—Bituminous coal; Jordan field; analyses Nos. 11370, 11371, 11372, and 11373 (p. 47).

Mine.—Pharis No. 1, a shaft mine in sec. 7, T. 41 N., R. 26 W., 2 miles east of Clinton, on the St. Louis & San Francisco Railroad.

Coal bed.—Jordan. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 1 foot 10 inches. The bed lies practically horizontal. Roof, blue shale 2½ feet thick overlain by calcareous shale 10 feet thick; floor, fire clay. Cover at point of sampling, 30 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 1, 1910.

Sample 11370 was taken at the face, 100 feet west of the shaft.

Sample 11371 was measured at the face, 100 feet south of the shaft.

Sample 11372 was measured at the face, 50 feet east of the shaft.

At each of the points sampled the bed was 1 foot 10 inches thick, with a 2-inch "sulphur" band about 8 inches from the top of the bed. This was excluded in sampling, each sample representing 1 foot 8 inches of coal.

A composite sample was made by combining face samples 11370, 11371, and 11372. The results of an ultimate analysis of this sample are given under laboratory No. 11373.

Notes.—The mine is opened by a shaft about 35 feet deep, and is worked by the room-and-pillar system. The daily output at the time of sampling was 14 tons.

CLINTON. SHELDON No. 1 MINE.

Sample.—Bituminous coal, Jordan field; analyses Nos. 11262, 11263, 11264, and 11265 (p. 47).

Mine.—Sheldon No. 1, a shaft mine in sec. 25, T. 41 N., R. 26 W., 3 miles southeast of Clinton, on the St. Louis & San Francisco Railroad and the Kansas City Southern Railway.

Coal bed.—Jordan. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 2 feet 2 inches. The bed lies practically horizontal. Roof, shale, 7 feet thick; floor, fire clay. Cover at points of sampling, 35 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on November 23, 1910.

Sample 11262 was taken at the face, 80 feet southwest of the shaft, and represents 2 feet 2 inches of clean coal.

Sample 11263 was taken at the face, 110 feet south of the shaft, and represents 2 feet 2 inches of clean coal.

Sample 11264 was taken at the face, 110 feet southeast of the shaft, and represents 2 feet 2 inches of clean coal.

At each of the points sampled the entire thickness of the bed was included.

A composite sample was made from face samples 11262, 11263, and 11264. The results of an ultimate analysis of this sample are given under laboratory No. 11265.

Notes.—The shaft is about 40 feet deep. The coal is mined by the longwall system. At the time of sampling the output was 20 tons a day.

DEEPWATER. DICKEY No. 1 PIT.

Sample.—Bituminous coal, Jordan field; analyses Nos. 11310, 11311, 11312, and 11313 (p. 47).

Mine.—Dickey No. 1, an open-pit mine in sec. 14, T. 40 N., R. 26 W., in the eastern part of the city of Deepwater, on the Kansas City, Clinton & Springfield Railway.

Coal bed.—Jordan. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 26 inches. The bed is horizontal. Roof, shale, 2 to 4 feet thick, overlain by 15 feet of clay and soil; floor, fire clay.

The bed was measured and sampled at three points in the pit by R. D. Killian on December 1, 1910.

Sample 11310 was taken at the face on the north side of the pit.

Sample 11311 was taken at the face on the east side of the pit.

Sample 11312 was taken at the face on the west side of the pit.

At each of the points sampled the bed was 2 feet 2 inches thick, with a 2-inch "sulphur" band about 8 inches from the top. This band was excluded from the samples, which represent 2 feet of coal.

A composite sample was made from face samples 11310, 11311, and 11312. The results of an ultimate analysis of this sample are given under laboratory No. 11313.

Notes.—The mine is worked as an open pit. At the time of sampling the output was 10 tons a day, for local use.

DEEPWATER. HURST NO. 1 MINE.

Sample.—Bituminous coal, Jordan field; analyses Nos. 11252, 11253, 11254, and 11255 (p. 47).

Mine.—Hurst No. 1, a shaft mine in sec. 13, T. 40 N., R. 26 W., three-fourths of a mile east of Deepwater, with connections to the St. Louis & San Francisco Railroad.

Coal bed.—Jordan. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 3 feet 4 inches. The bed lies practically horizontal. Roof, dark gray shale; floor, soft clay. Cover, 54 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on November 26, 1910.

Sample 11252 was taken at the face, 100 feet northeast of the shaft, and represents 3 feet 4 inches of clean coal.

Sample 11253 was taken at the face, 350 feet west of the shaft, and represents 3 feet 4 inches of clean coal.

Sample 11254 was taken at the face, 450 feet northwest of the shaft, and represents 3 feet 4 inches of clean coal.

At each of the points sampled the entire thickness of the bed was included.

A composite sample was made by combining face samples 11252, 11253, and 11254. The results of an ultimate analysis of this sample are given under laboratory No. 11255.

Notes.—The shaft is 60 feet deep. The room-and-pillar system of mining is employed. The coal is delivered to the railroad by a tramway 1,100 feet long. At the time of sampling the output was 65 tons a day. The coal was marketed in the neighboring towns along the Frisco Railroad.

LEWIS. PIGG NO. 1 MINE.

Sample.—Bituminous coal, Lewis field; analyses Nos. 11267, 11268, 11269, and 11270 (p. 48).

Mine.—Pigg No. 1, a shaft mine in sec. 9, T. 42 N., R. 25 W., three-fourths of a mile north of Lewis, connected by a tramway to the Missouri, Kansas & Texas Railway.

Coal bed.—Tebo. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 2 feet 6 inches. The bed lies practically horizontal. Roof, shale 3 feet thick, overlain by hard limestone 10 to 20 inches thick; floor, soft clay. Cover at points of sampling, 34 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian, on November 28, 1910.

Sample 11267 was taken at the face, 1,300 feet west of the shaft, and represents 2 feet 6 inches of clean coal.

Sample 11268 was taken at the face, 1,300 feet southwest of the shaft, and represents 2 feet 6 inches of coal.

Sample 11269 was taken at the face, 1,400 feet southwest of the shaft, and represents 2 feet 6 inches of coal.

At each of the points sampled the entire thickness of the bed was included.

A composite sample was made by combining face samples 11267, 11268, and 11269. The results of an ultimate analysis of this sample are given under laboratory No. 11270.

Notes.—The mine is opened by a shaft 50 feet deep and is worked by the longwall system. At the time of sampling, punching machines operated by compressed air were used for undercutting the coal. The daily output was 65 tons.

LINN COUNTY.

BROOKFIELD. CRANDALL NO. 1 MINE.

Sample.—Bituminous coal; Marceline field; analyses Nos. 11421, 11422, 11423, and 11424 (p. 48).

Mine.—Crandall No. 1, a shaft mine in sec. 20, T. 57 N., R. 19 W., 1¾ miles east of Brookfield near the Chicago, Burlington & Quincy Railroad.

Coal bed.—Tebo. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 2 feet 2 inches. The bed lies horizontal. Roof, fire clay, 4 inches thick, overlain by blue shale 51 feet thick; floor, soft fire clay 3 inches thick, underlain by hard clay. Cover, 155 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian, on December 12, 1910.

Sample 11421 was taken at the face, 750 feet southeast of the shaft.

Sample 11422 was taken at the face, 750 feet southwest of the shaft.

Sample 11423 was taken at the face, 800 feet east of the shaft.

At each of the points sampled the bed was 2 feet 5 inches thick, with a 3-inch parting of soft fire clay, about 2 feet 2 inches from the top. Each sample represents 2 feet 2 inches of coal, the parting being excluded.

A composite sample was made by combining face samples 11421, 11422, and 11423. The results of an ultimate analysis of this sample are given under laboratory No. 11424.

Notes.—The shaft is 140 feet deep. The longwall system of mining is employed. At the time of sampling the daily output was 20 tons. The entire output was sold in and around Brookfield.

BROOKFIELD. WALKER NO. 1 MINE.

Sample.—Bituminous coal; Marceline field; analyses Nos. 11413, 11414, 11415, and 11416 (p. 49).

Mine.—Walker No. 1, a shaft mine in sec. 16, T. 57 N., R. 19 W., 3 miles southeast of Brookfield, on the Chicago, Burlington & Quincy Railroad.

Coal bed.—Tebo. Carboniferous age, Pennsylvanian series, Cherokee formation. Thickness, 2 feet 2 inches. The bed lies practically horizontal. Roof, blue shale; floor, soft clay 4 inches thick, underlain by hard clay. Cover at points of sampling, 170 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 12, 1910.

Sample 11413 was taken at the face, 250 feet southwest of the shaft.

Sample 11414 was taken at the face, 200 feet northeast of the shaft.

Sample 11415 was taken at the face, 200 feet southeast of the shaft.

At each of the points sampled the bed was 2 feet 2 inches thick, all of which is represented in the samples.

A composite sample was made by combining face samples 11413, 11414, and 11415. The results of an ultimate analysis of this sample are given under laboratory No. 11416.

Notes.—The shaft is about 175 feet deep. The mine is worked by the longwall method. At the time of sampling the daily output was 10 tons; it was used locally.

MARCELINE. LANDRETH NO. 1 MINE.

Sample.—Bituminous coal; Marceline field; analyses Nos. 11417, 11418, 11419, and 11420 (p. 49).

Mine.—Landreth No. 1, a shaft mine in sec. 20, T. 57 N., R 18 W., three-fourths of a mile west of Marceline, near the Atchison, Topeka & Santa Fe Railway.

Coal bed.—Tebo. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 2 feet 4 inches. The bed lies practically horizontal. Roof, soft blue shale 31 feet thick; floor, clay. Cover, 130 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 13, 1910.

Sample 11417 was taken at the face, 600 feet east of the shaft, and represents 2 feet 4 inches of clean coal.

Sample 11418 was taken at the face, 600 feet north of the shaft, and represents 2 feet 4 inches of clean coal.

Sample 11419 was taken at the face, 600 feet south of the shaft, and represents 2 feet 4 inches of coal.

At each of the points sampled the entire thickness of the bed was included.

A composite sample was made by combining face samples 11417, 11418, and 11419. The results of an ultimate analysis of this sample are given under laboratory No. 11420.

Notes.—The mine is opened by a shaft about 130 feet deep, and is worked by the longwall system. At the time of sampling the daily output was 25 tons. The coal is hauled by wagon to Marceline, where it is used for domestic and steaming purposes.

PUTNAM COUNTY.

MENDOTA. MENDOTA NO. 2 MINE.

Sample.—Bituminous coal; Mendota field; analyses Nos. 11398, 11399, 11400, and 11401 (p. 49).

Mine.—Mendota No. 2, a shaft mine in sec. 1, T. 66 N., R. 18 W., 1 mile southeast of Mendota on the Chicago, Burlington & Quincy Railroad.

Coal bed.—Lexington. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 3 feet. The bed lies horizontal. Roof, shale 18 inches thick, overlain by calcareous shale 16 feet thick; floor, hard fire clay. Cover, 65 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 10, 1910.

Sample 11398 was taken at the face, 2,500 feet southwest of the shaft.

Sample 11399 was taken at the face, 3,200 feet south of the shaft.

Sample 11400 was taken at the face, 3,100 feet southeast of the shaft.

At each of the places sampled the coal was 3 feet thick, with a 2-inch clay parting about the middle of the bed. The parting was excluded from the samples.

A composite sample was made from face samples 11398, 11399, and 11400. The results of an ultimate analysis of this sample are given under laboratory No. 11401.

Notes.—The shaft is 67 feet deep. A combination of the room-and-pillar and the longwall systems of mining are used. At the time of sampling the output was 100 tons a day. The coal was used for domestic fuel and steaming purposes.

UNIONVILLE. ANDERSON MINE.

Sample.—Bituminous coal; Mendota field; analyses Nos. 14880 and 14881 (p. 49).

Mine.—Anderson, a shaft mine, Unionville district; NW. ¼ sec. 30, T. 66 N., R. 19 W.; 2¼ miles northeast of Unionville.

Coal bed.—Lexington. Carboniferous age; Pennsylvanian series; Cherokee shale. Roof, black "slaty" shale, overlain by limestone; floor, clay. Thickness, 32 inches, fairly uniform.

The bed was measured and sampled at two points in the mine by M. Albertson on October 10, 1912, as described below·

Sections of coal bed in Anderson mine.

Section	A		B	
Laboratory No.	14880		14881	
	Ft.	*in.*	*Ft.*	*in.*
Coal	1	7	1	6
Clay	[a] 0	2¼	[a] 0	2¼
Coal	0	11	0	11
Clay	..	..	[a] 0	1½
Coal	..	..	0	1½
Thickness of bed	2	8¼	2	10¼
Thickness of coal sampled	2	6	2	6½

[a] Excluded from sample.

Section A (sample 14880) was taken 175 feet southwest of the shaft.

Section B (sample 14881) was taken 150 feet east of the shaft.

RANDOLPH COUNTY.

HUNTSVILLE. CARSON NO. 1 MINE.

Sample.—Bituminous coal, Bevier field; analyses Nos. 11452, 11453, 11454, and 11455 (p. 50).

Mine.—Carson No. 1, a shaft mine in the Huntsville district; sec. 36, T. 54 N., R. 15 W.; in the southern part of Huntsville, on the Wabash Railroad.

Coal bed.—Bevier. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 4 feet. The bed lies horizontal. Roof, blue calcareous shale 20 feet thick; floor, hard fire clay. Cover at points of sampling, 40 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 14, 1910.

Sample 11452 was taken at the face, 250 feet southeast of the shaft, and represents 4 feet of clear coal, the thickness of the bed.

Sample 11453 was taken at the face, 300 feet north of the shaft, and represents 4 feet of clear coal, the thickness of the bed.

Sample 11454 was taken at the face, 200 feet southwest of the shaft, and represents 4 feet of clear coal, the thickness of the bed.

A composite sample was made by combining face samples 11452, 11453, and 11454. The results of an ultimate analysis of this sample are given under laboratory No. 11455.

Notes.—The mine is opened by a shaft about 40 feet deep; it is worked by the room-and-pillar system. At the time of sampling the daily output was 10 tons. The coal is sold in the local markets at Huntsville.

HUNTSVILLE. NORTHERN NO. 2 MINE.

Sample.—Bituminous coal; Bevier field; analyses Nos. 11448, 11449, 11450, and 11451 (p. 50).

Mine.—Northern No. 2, a shaft mine in the Huntsville district; SE. ¼ sec. 36, T. 54 N., R. 15 W.; three-fourths of a mile south of Huntsville, on the Wabash Railroad.

Coal bed.—Bevier. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 4 feet. The bed lies horizontal. Roof, blue calcareous shale 30 feet thick; floor, hard fire clay. Cover at points of sampling 70 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 14, 1910.

Sample 11448 was taken at the face, 4,000 feet south of the shaft, and represents 4 feet of clear coal.

Sample 11449 was taken at the face, 3,800 feet northeast of the shaft, and represents 4 feet of clear coal.

Sample 11450 was taken at the face, 3,500 feet southeast of the shaft, and represents 4 feet of clear coal.

A composite sample was made by combining face samples 11448, 11449, and 11450. The results of an ultimate analysis of this sample are given under laboratory No. 11451.

Notes.—The shaft is about 70 feet deep; the room-and-pillar system of mining is used. At the time of sampling the output was 600 tons a day.

RENICK. ORRIS NO. 1 MINE.

Sample.—Bituminous coal; Bevier field; analyses Nos. 11497, 11498, 11499, and 11500 (pp. 50, 51).

Mine.—Orris No. 1, a shaft mine in the Higbee district; sec. 31, T. 53 N., R. 13 W., one-quarter mile west of Renick, on the Wabash Railroad.

Coal bed.—Mulky. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness 1 foot 6 inches. The bed lies horizontal. Roof, shale 4 feet thick, overlain by limestone 6 feet thick; floor, fire clay 1 foot 6 inches thick. Cover at points of sampling, 60 feet.

The bed was measured and sampled at three places in the mine by R. D. Killian on December 15, 1910.

Sample 11497 was taken at the face, 300 feet southwest of the shaft.

Sample 11498, was taken at the face, 300 feet northwest of the shaft.

Sample 11499 was taken at the face, 300 feet west of the shaft.

At each of the points sampled the bed was 1 foot 6 inches thick, all of which was included in sampling.

A composite sample was made by mixing face samples 11497, 11498, and 11499. The results of an ultimate analysis of this sample are given under laboratory No. 11500.

Notes.—The shaft is about 60 feet deep; the room-and-pillar system of mining is employed. At the time of sampling the daily output was 10 tons; the coal was sold in local markets.

RAY COUNTY.

VIBBARD. VIBBARD NO. 1 MINE.

Sample.—Bituminous coal; Lexington field; analyses Nos. 11365, 11366, 11367, and 11368 (p. 51).

Mine.—Vibbard No. 1, a shaft mine in the Richmond district; sec. 27, T. 53 N., R. 29 W.; one-fourth of a mile south of Vibbard, on the Atchison, Topeka & Santa Fe Railway.

Coal bed.—Lexington. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 2 feet 2 inches. The bed lies horizontal. Roof, "slate" 8 inches thick, overlain by calcareous shale 7 feet thick; floor, clay. Cover at points of sampling, 400 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on December 5, 1910.

Sample 11365 was taken at the face, 250 feet south of the shaft.

Sample 11366 was taken at the face, 250 feet east of the shaft.

Sample 11367 was taken at the face, 200 feet west of the shaft.

At each of the points sampled the bed was 2 feet 2 inches thick, with a 2-inch "sulphur" band 8 inches from the top. Each sample represents 2 feet of coal, the 2-inch band being excluded.

A composite sample was made by combining face samples 11365, 11366, and 11367. The results of an ultimate analysis of this sample are given under laboratory No. 11368.

Notes.—The mine is worked by the longwall system; at the time of sampling the output was 12 tons a day. The coal was sold in the local market.

VERNON COUNTY.

MOUNDVILLE. BROWN NO. 1 MINE.

Sample.—Bituminous coal; analyses Nos. 11201, 11202, 11203, and 11204 (p. 51).

Mine.—Brown No. 1, a shaft mine in sec. 5, T. 34 N., R. 32 W., at the northwest corner of Moundville, on the Missouri Pacific Railway.

Coal bed.—Not correlated. Carboniferous age, Pennsylvanian series. Thickness, 5 feet 10 inches. The bed lies horizontal. Roof, dark bluish shale 8 feet thick; floor, hard shale. Cover at points of sampling, 28 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on November 15, 1910.

Sample 11201 was taken at the face, 40 feet northwest of the shaft.

Sample 11202 was taken at the face, 100 feet northeast of the shaft.

Sample 11203 was taken at the face, 125 feet north of the shaft.

Each sample represents 2 feet 2 inches of coal. A lower bench of coal, 2 feet 4 inches thick, was separated from the one sampled by 1 foot 4 inches of shale.

A composite sample was made by combining face samples 11201, 11202, and 11203. The results of an ultimate analysis of this sample are given under laboratory No. 11204.

Notes.—The shaft is 26 feet deep; the mine is worked by room-and-pillar system. At the time of sampling the daily output was 40 tons.

PANAMA. JONES NO. 1 MINE.

Sample.—Bituminous coal; Rich Hill field; analyses Nos. 11205, 11206, 11207, and 11208 (p 51).

Mine.—Jones No. 1, a shaft mine in sec. 4, T. 37 N., R. 31 W., 2 miles south of Panama, on the Missouri Pacific Railway.

Coal bed.—Rich Hill. Carboniferous age, Pennsylvanian series, Cherokee shale. Thickness, 5 feet. The bed lies practically horizontal. Roof, shale 1 foot thick; floor, soft shale. Cover 40 to 60 feet.

The bed was measured and sampled at three points in the mine by R. D. Killian on November 16, 1910.

Sample 11205 was taken at the face, 450 feet east of the shaft.

Sample 11206 was taken at the face, 1,000 feet southeast of the shaft.

Sample 11207 was taken at the face, 100 feet east of the shaft.

At each of the points sampled the coal bed was 5 feet thick. Above the coal was a "sulphur" band 5 inches thick, which was overlain by the shale roof. There was shale below the coal.

A composite sample was made by combining face samples 11205, 11206, and 11207. The results of an ultimate analysis of this sample are shown under laboratory No. 11208.

Notes.—The shaft is 27 feet deep; the mine is worked by the room-and-pillar system. At the time of sampling the coal was blasted off the solid; the daily output was 100 tons.

MONTANA.

BLAINE COUNTY.

CLEVELAND. COOK MINE.

Sample.—Subbituminous coal; Cleveland field; analysis No. 14782 (p. 52).

Mine.—Cook; SW. ¼ sec. 35, T. 30 N., R. 20 E., about 4 miles northeast of Cleveland post office.

Coal bed.—Not named; Judith River formation; Cretaceous age. The bed was measured and sampled at one point in the mine by C. F. Bowen and Harvey Bassler on September 22, 1912, as shown below:

Section of coal bed in Cook mine.

Laboratory No	14782
Roof, shale.	*Ft. In.*
Coal	1 3
Clay	[a]0 5½
Coal	1 10
Floor, shale.	
Thickness of bed	3 6½
Thickness of coal sampled	3 1

[a] Not included in sample.

The sample was taken from the face of the entry, about 500 feet from the mine mouth.

Notes.—The mine was operated during the winter months and has an output of about 600 tons a year.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 541. (In press).

CARBON COUNTY.

BEAR CREEK. No. 2 MINE.

Sample.—Subbituminous coal; Red Lodge field; analyses Nos. 15145 and 15151; 15146 and 15152; 15147 and 15153; 15148 and 15154; 15149 and 15155; and 15150 and 15156. (pp. 52, 53).

Mine.—No. 2, a drift mine in sec. 6, T. 8 S., R. 21 E., 1½ miles west of Bear Creek, on the Montana, Wyoming & Southern Railroad.

Coal bed.—No. 2, Tertiary age, Fort Union formation. Average thickness, 6 feet 6 inches; dip, about 5° southwest, not uniform. Roof, dark shale 4 to 10 feet thick, overlain by sandstone; floor, soft smooth fire clay. Particles of the roof and floor did not mix with the coal in mining. Cover at the points of sampling, 85 to 105 feet.

The bed was measured and sampled at five points in the mine by O. U. Bradley on November 28 to 30, 1912, as described below:

Sections of coal bed in No. 2 mine.

Section	A	B	C	D	E
Laboratory No	15145 15151	15146 15152	15147 15153	15148 15154	15149 15155
Roof, clay (overlain by shale).	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	0 4	0 6	0 5	0 7	0 5
Coal, bony	0 3	0 ½	0 3	0 3½	0 2½
Coal	2 7	2 8	4 10½	2 8	2 5
Clay and bony coal	0 1	0 ½	.. ..	0 ½	0 ½
Coal	0 3	.. ..	.. ..	0 3¼	0 3
Clay or bony coal	0 ½	.. ..	.. ..	0 ½	0 ½
Coal	2 8	3 1	.. ..	2 5	2 4½
Floor, fire clay.					
Thickness of bed	6 2½	6 4	5 6½	6 3¾	5 9
Thickness of coal sampled	6 2½	6 4	5 6½	6 3¾	5 9

Section A (samples 15145 and 15151) was measured on a pillar between rooms 9 and 10, off north entry 2.

Section B (samples 15146 and 15152) was measured at the face of room 10; 125 feet off west entry 1.

Section C (samples 15147 and 15153) was measured at the face of room 9, 45 feet off east entry 9.

Section D (samples 15148 and 15154) was measured at the face of the cut-through in room 22, off east entry 4.

Section E (samples 15149 and 15155) was measured at the face of room 11, 35 feet off rock tunnel entry.

A composite sample was made by mixirg samples.15146, 15147, 15148, and 15149. The results of an ultimate analysis of this sample are shown under laboratory No. 15150.

A composite sample was made by mixing samples Nos. 15152, 15153, 15154, and 15155. The results of an ultimate analysis of this sample are shown under laboratory No. 15156.

Notes.—The coal is mined by the room-and-pillar system. At the time of sampling, the coal was undercut by chain cutting machines and broken down with FF black blasting powder. None of the coal was shipped as run-of-mine. The tipple was equipped with shaking screens 12 feet long and 5 feet wide with openings 2½ by 4 inches, screens 5 feet wide and 12 feet long, with 2-inch openings, and a revolving screen 12 feet long with ¾ and 1¼ inch openings. About 50 per cent of the coal passed through the larger screens. The screenings were conveyed by an aerial tramway to the dirt dump. There were no pickers employed. The lumps were large and appeared to be clean coal. There were two loading tracks with a capacity of 20 empty and 20 loaded cars. The daily output of the mine was about 800 tons. The intent was to increase the output to 1,000 or 1,200 tons when the No. 3 seam is opened.

BEAR CREEK. NORTH SIDE AND SOUTH SIDE MINES.

Sample.—Subbituminous coal; Red Lodge field; analyses Nos. 15127 and 15133, 15128 and 15132, 15129 and 15131, 15143 and 15144, and 15130 and 15134 (p. 53).

Mine.—The North Side and South Side mines are opened by drifts in sections 5 and 6, T. 8 S., R. 21 E. The tipple is 1 mile west of Bear Creek, on the Montana, Wyoming & Southern Railroad.

Coal bed.—No. 3, Tertiary age, Fort Union formation. Average thickness, 6 feet 3 inches; dip, about 4° southwest. The cleat is poorly defined. The coal bed has two irregular bone partings. The roof is a dark blue shale which occasionally comes down with the coal; above the shale is a sandstone cap rock. The floor is a soft smooth fire clay. There is a workable coal bed 80 feet above and one 60 feet below this bed. At the time of sampling, particles of the roof and floor mixed with the coal in mining. Cover at the points of sampling, 75 to 130 feet.

The bed was measured and sampled at three points in the South Side mine on November 25, 1912, and at one point in the North Side mine on December 1, 1912, by O. U. Bradley, as described below:

Sections of coal bed in South Side mine.

Section	A		B		C	
Laboratory No.	15127 15133		15128 15132		15129 15131	
Roof, blue shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	5	6	5	7	5	1
Clay and bone	[a]0	8	[a]0	4	[a]0	5
Coal	0	7	..	..	0	7
Bone	[a]0	4	..	..	[a]0	2
Coal	0	10	1	9	0	11
Floor, clay.						
Thickness of bed	7	11	7	8	7	2
Thickness of coal sampled	6	11	7	4	6	7

[a] Not included in sample.

Section A (samples 15127 and 15133) was measured at the face of room 2, off north entry 1, 50 feet in from entry.

Section B (samples 15128 and 15132) was measured in the crosscut from the main entry to the back entry, 350 feet from the mouth of the main entry and 75 feet from the face of the back entry.

Section C (samples 15129 and 15131) was measured at the face of the first south back entry, 150 feet from the main slope.

A composite sample was made by mixing samples 15127, 15128, and 15129. The results of an ultimate analysis of this sample are given under laboratory No. 15130.

A composite sample was made by mixing samples 15131, 15132, and 15133. The results of an ultimate analysis of this sample are given under laboratory No. 15134.

Section of coal bed in North Side mine.

Laboratory No.	15143 15144	
Roof, blue shale.	*Ft.*	*in.*
Coal	1	11
Clay and bone	0	1
Coal	0	6
Bone	0	1
Coal	2	11
Floor, clay.		
Thickness of bed	5	6
Thickness of coal sampled	5	6

The above section (samples 15143 and 15144) was measured on the last pillar on the second west main entry, 500 feet from the drift mouth.

Notes.—At the time of sampling the North Side mine was almost worked out; advance work being completed. It was estimated that all the pillars would be withdrawn within one and one-half years. Twenty-seven inches or more of bottom coal had been left in the mine.

The South Side mine was a new mine on the opposite side of the gulch from the North Side mine. The coal was delivered to the North Side tipple over a wooden trestle 1,600 feet long, with a 4 per cent grade. At the time of sampling all the workings in the South Side mine were narrow. The coal was cut in the 4 to 8-inch parting with machines and the top coal mined three cuts ahead of the bottom coal. This was the first mine in the district to mine the bottom coal of the No. 3 bed; the lower bench averages 27 inches in thickness. The coal was broken down with FF black blasting powder. Dynamite was sometimes used for brushing the roof and floor.

The screening equipment consisted of shaking screens 16 feet long and 6 feet wide, in three sections: an 8-foot section with 2-inch openings, a 4-foot section with 4-inch openings, and a 4-foot section with 6-inch openings; a small shaking screen 14 feet long and 6 feet wide, in two sections: an 8-foot section with 1¼-inch openings and a 6-foot section with 1½-inch openings; and a revolving screen 12 feet long with ¾-inch openings. Four per cent of the coal was shipped as run-of-mine. Sixty-five per cent of the coal going to the screens passed through the 6-inch openings. Pickers were employed on picking tables. The lumps were large and had a good appearance. There were three loading tracks with a capacity of 25 empty and 25 loaded cars. The daily output was 300 tons. There was about 600 acres of unmined coal tributary to the tipple.

CHOUTEAU COUNTY.

BIG SANDY. MACKTON MINE.

Sample.—Subbituminous coal; Big Sandy field; analyses Nos. 14613 and 14615 (p. 54).

Mine.—Mackton; NW. ¼ SW. ¼ sec. 18, T. 28 N., R. 14 E., 6 miles northeast of Big Sandy.

Coal bed.—Mackton. Tertiary age, Fort Union formation. Thickness about 7½ feet; dip 40° east.

The bed was measured and sampled at two points in the mine by C. F. Bowen and Harvey Bassler on August 12, 1912, as shown below:

Sections of coal bed in Mackton mine..

Section	A	B
Laboratory No.	14613	14615
Roof, sandstone.	*Ft. in.*	*Ft. in.*
Coal	2 5	1 5
Bone	[a]0 2	[a]0 2
Coal	0 6	1 3
Bone and coal	[a]1 9	[a]1 3
Coal	2 7	3 5
Floor, sandstone.		
Thickness of bed	7 5	7 6
Thickness of coal sampled	5 6	6 1

[a] Not included in sample.

Section A (sample 14613) was measured at the face of the north entry on the second level, 335 feet below the mouth of the slope and 140 feet from the mouth of the entry.

Section B (sample 14615) was measured at the face of the south entry on the first level, 150 feet below the mouth of the slope and 250 feet south of the mouth of the entry.

Sample 14613 represents perfectly fresh coal. Sample 14615 represents coal on which no mining had been done for nearly a year and was probably somewhat weathered.

Notes.—The dip and thickness of the bed are fairly uniform in the mine. The output was about 100 tons a day during the winter months but was less in the summer season.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 128, 595.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 541, 1914. (In press.)

CUSTER COUNTY.

TERRY. CAMERON MINE.

Sample.—Lignite; Terry field; analysis No. 10677 (p. 54).

Mine.—Cameron, an open-pit mine in sec. 24, T. 12 N., R. 50 E., about 4 miles west of Terry, which is the nearest station on the Northern Pacific Railway and the Chicago, Milwaukee & St. Paul Railway. The mine is about one-fourth of a mile south of the railroads.

Lignite bed.—Unnamed. Tertiary age, Fort Union formation. Thickness, 7 feet 5 inches. Roof, soft white sandstone; floor, shale. The bed was measured and sampled at one point in the pit by F. A. Herald on July 15, 1910, as described below:

Section of lignite bed in Cameron mine.

Laboratory No.	10677
Roof, soft sandstone.	*Ft. in.*
Lignite	[a]0 8
Parting	[a]0 8
Lignite	[a]3 4
Lignite	3 5
Floor, shale.	
Thickness of bed	8 1
Thickness of coal sampled	3 5

[a] Not included in sample.

The 3 foot 4 inch bench above the part sampled was apparently as good lignite as the lower part of the bed, although it was reported at the mine that it burns quickly and does not give out as much heat. At the time of sampling the mine was worked as an open pit and the output was only one or two wagon loads a day.

For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 246.

Westmore. Prospect.

Sample.—Lignite; Baker field; analysis No. 10910 (p. 54).

Mine.—Prospect opening in sec. 34, T. 6 N., R. 57 E., about 17 miles south of Westmore, which is the nearest railroad station on the Chicago, Milwaukee & St. Paul Railway.

Lignite bed.—Unnamed. Tertiary age, Fort Union formation. Thickness, 4 feet 3 inches. Above the lignite is 2 inches of bituminous shale, overlain by a top clay. On account of the excessive amount of water in the opening the character of the floor could not be determined. The bed was sampled by C. F. Bowen on September 13, 1910. At the time this sample was taken the prospect was not being worked.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 471, 1912, p. 220.

DAWSON COUNTY.

Glendive. Prospect.

Sample.—Lignite; Sidney field; analysis No. 10914 (p. 54).

Mine.—Prospect in SW. ¼ sec. 31, T. 18 N., R. 57 E., 15 miles northeast of Glendive, which is the nearest station on the Northern Pacific Railway.

Lignite bed.—B. Tertiary age, Fort Union formation. Thickness, 5 feet. Roof, white clay; floor, grayish clay. The bed was sampled by Eugene Stebinger on July 25, 1910. The sample was taken on the right wall, 25 feet from the outcrop. The entry was caved and evidently had not been worked for some years.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull, 471, 1912, p. 297.

Glendive. Snyder Mine.

Sample.—Lignite; Glendive field; analysis No. 11045 (p. 54).

Mine.—Snyder, NW ¼ sec. 27, T. 17 N., R. 55 E., about 6½ miles north of Glendive, which is the nearest station on the Northern Pacific Railway. The mine is about 6 miles from the railroad.

Lignite bed.—Second or middle bed, not named. Tertiary age, Fort Union formation. Thickness, about 8 feet. The bed was sampled at one point in the mine by J. H. Hance on October 4, 1910. The sample was taken at the working face, about 80 feet from the mine mouth.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 130, 610.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 471, 1912, p. 278.

FERGUS COUNTY.

Hilger. Stone Mine.

Sample.—Subbituminous coal, Lewistown field; analysis No. 14495 (p. 54).

Mine.—Stone; sec. 8, T. 19 N., R. 19 E., about 13 miles north of Hilger.

Coal bed.—Not named. Cretaceous age, Judith River formation. The bed was measured and sampled at one point in the mine by C. F. Bowen and Harvey Bassler on July 26, 1912, as shown below:

Section of coal bed in Stone mine.

Laboratory No.	14495	
Roof, shale.	*Ft.*	*in.*
Coal	2	0
Clay	[a]0	7
Coal	0	8
Shale	[a]0	4
Coal	0	6
Shale	[a]0	2
Coal	0	9
Sandstone	[a]0	2
Bone	[a]0	5
Coal	0	5+
Floor, not stated.		
Thickness of bed	6+	0
Thickness of coal sampled	4	4

[a] Not included in sample.

The sample was taken at the face of the entry, 140 feet from the mine mouth and represents fresh coal.

Notes.—At the time of sampling the mine was not a regular producer. The coal was used chiefly as fuel for traction engines.

For a description of the geologic relations of this bed see U. S. Geol. Survey Bull. 541.

FLATHEAD COUNTY.

FLATHEAD RIVER. OUTCROP.

Sample.—Subbituminous coal; Glacier Park field; analysis No. 12786 (p. 55).

Location.—Natural outcrop in bank of North Fork of Flathead River, in sec. 33, T. 34 N., R. 20 W.

Coal bed.—Not named. Tertiary age. The bed was measured and sampled below water level by M. R. Campbell on October 2, 1911, as follows:

Section of coal bed in outcrop in sec. 33, T. 34 N., R. 20 W.

Laboratory No.	12786	
	Ft.	*in.*
Coal	2	6
Clay	[a]0	8
Coal	1	0
Clay	[a]0	2
Coal	[a]0	10
Clay	[a]0	8
Coal	[a]0	11
Thickness of bed	6	9
Thickness of coal sampled	3	6

[a] Not included in sample.

Notes.—The coal represented by the sample was weathered. At the time the sample was taken, no coal had been mined in this valley.

MISSOULA COUNTY.

MISSOULA. HELL GATE MINE.

Sample.—Subbituminous coal; analyses Nos. 13541 and 13542.

Mine.—Hell Gate, a slope mine in sec. 4, T. 13 N., R. 19 W., 2 miles north of Missoula.

Coal bed.—Unnamed; in Tertiary lake beds, probably the White River formation of Oligocene age.

Sample 13541 was taken by J. T. Pardee on September 30, 1911, from coal in the bunker at the mouth of the mine and represented run-of-mine coal from a bed 6 feet thick in the east entry.

Sample 13542, as reported, was taken by H. L. Shapard in the east entry, 300 feet from the slope, and represented 6 feet 10 inches of coal.

Notes.—At the time the mine was visited the coal was used for local purposes. It slacks on exposure and will not stand storage nor transportation to any considerable distance.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 531, p. 241.

MUSSELSHELL COUNTY.

PAINTED ROCK. SHOLZ MINE.

Sample.—Subbituminous coal; analysis No. 15114 (p. 55).

Mine.—Sholz, a drift mine near the Great Northern Railway, NW. ¼ sec. 14, T. 5. N., R. 22 E., near Painted Rock.

Coal bed.—Unnamed. Cretaceous age; Judith River formation; lenticular, maximum thickness 44 inches.

The bed was measured and sampled at one place in the mine by E. G. Woodruff on September 10, 1912.

The mine consisted of two drifts, a north one 110 feet long, and a south one 80 feet long. The sample was taken from a working face at the end of the longer drift, and represents 2 feet 11 inches of coal. There was shale interlaminated with coal above the part sampled, and sandy shale below it.

ROSEBUD COUNTY.

BIGHORN. PROSPECT.

Sample.—Subbituminous coal; Tullock Creek field; analysis No. 14755 (p. 55).

Location.—Prospect in the NW. ¼ NE. ¼ sec. 2, T. 4 N., R. 35 E., on Unknown Creek, 6½ miles east of Bighorn. No railroad connection.

Coal bed.—Not named. Cretaceous or Tertiary age; Lance formation. Character, variable and lenticular.

The bed was measured and sampled by C. E. Lesher and G. S. Rogers on September 18, 1912.

Section of coal bed in prospect, 6½ miles east of Bighorn.

Laboratory No.	14755	
Roof, shale and thin sandstone.	*Ft.*	*In.*
Coal	[a]0	1
Sandstone	[a]0	¼
Shale	[a]0	1¾
Coal	0	8
Bone	[a]0	1¾
Coal	0	8
Coal, dirty	0	3
Coal, hard	1	2½
Floor, shale.		
Thickness of bed	3	2¼
Thickness of coal sampled	2	9½

[a] Not included in sample.

The sample was taken 10 feet from the surface at a freshly exposed face, but probably represented coal from the weathered part of the bed. No mining had been done at this prospect.

TETON COUNTY.

BROWNING. J. M. STONE PROSPECT.

Sample.—Bituminous coal; Blackfoot field; analysis No. 12602 (p. 55).

Mine.—J. M. Stone prospect, SE. ¼ sec. 35, T. 36 N., R. 12 W., on middle fork of Milk River, 22 miles northwest of Browning.

Coal bed.—The bed occurs at the top of a coarse gray sandstone formation of Upper Cretaceous age. Roof, clay-shale 2 feet thick, overlain by gray sandstone; floor, clay. Thickness, 2 feet 8 inches; dip, 40° northeast. The bed is in a folded and faulted belt of rocks. The coal is without a parting, and has a fine cubic grain, a graphite black color, and a jointed structure suggesting torsion due to folding. The bed was measured and sampled at one point in the mine by Eugene Stebinger on September 10, 1911.

Notes.—The sample was cut from the face of the entry, 50 feet in. The coal was probably slightly weathered. Mined only occasionally for domestic use.

CUT BANK. ALLISON PROSPECT.

Sample.—Bituminous coal; analysis No. 12494 (p. 55).

Mine.—Prospect of A. E. Allison, NE. ¼ sec. 29, T. 34 N., R. 6 W., on Cutbank Creek, 5 miles northwest of Cut Bank.

Coal bed.—An unnamed coal bed occurring 225 feet above the base of the Two Medicine formation, Upper Cretaceous age. Lies nearly flat, dipping only about 40 feet per mile westward. Roof and floor are both gray clay, the coal lays on a persistent massive gray sandstone bedrock 30 to 50 feet thick.

The coal is 1 foot 10 inches thick and is very dirty, containing occasional streaks of clean hard coal. The bed was measured and sampled by Eugene Stebinger on July 24, 1911.

Notes.—The sample represents partly weathered coal from the prospect entry, under 25 feet of cover. Attempts to sell this coal for local use were not successful.

CUT BANK. PROSPECT.

Sample.—Bituminous coal; analysis No. 14109 (p. 55).

Mine.—Prospect open cut; SW. ¼ sec. 26, T. 33 N., R. 6 W.; on bank of Spring Creek, 4 miles southwest of Cut Bank.

Coal bed.—An unnamed coal bed occurring 225 feet above the base of the Two Medicine formation, Upper Cretaceous age. Thickness, 11 inches. Bed lies almost flat, dipping only 40 feet to the mile to the west. The roof and floor are both of gray clay. The coal is clean, with well-marked joint planes. The bed was measured and sampled by Eugene Stebinger on June 13, 1912.

The sample was taken in a fresh open cut under 4 feet of cover, and represents partly weathered coal.

VALIER. BLAIR MINE.

Sample.—Bituminous coal; Valier field; analysis No. 12427 (p. 55).

Mine.—A. G. Blair, a drift mine in the NW. ¼ sec. 32, T. 31 N., R. 5 W., on Birch Creek, 8 miles northwest of Valier.

Coal bed.—The only workable bed occurring at the top of the Eagle sandstone, of Upper Cretaceous age. The bed lies nearly flat, dipping westward only 20 to 30 feet to the mile. Roof, dark gray clay-shale, containing a few lenses of massive gray sandstone lying directly on the coal; floor, clay. The bed was measured and sampled at one place in the mine by Eugene Stebinger on July 12, 1911, as described below.

Section of coal bed in Blair mine.

Laboratory No.	12427	
	Ft.	*in.*
Coal	0	5
Bone	[a]0	2
Coal	1	10
Thickness of bed	2	5
Thickness of coal sampled	2	3

[a] Not included in sample.

Notes.—The sample was taken at the face of a new entry in 150 feet, in freshly mined coal. The upper 5 inches was hard coal with shiny black faces and showing some whitish dirt. The bone parting was persistent and regular. The lower bench, 1 foot 10 inches thick, was hard and fairly clean, with prominent joint planes, causing the coal to break in large blocks. At the time of sampling the mine was worked intermittently, employing up to 10 men, supplying a local trade in the vicinity of Valier and competing successfully with coal from the Great Falls field and Canadian coal from Lethbridge, Alta.

VALLEY COUNTY.

Antelope. Richardson Mine.

Sample.—Lignite; Plentywood field; analysis No. 14614 (p. 55).

Mine.—Richardson; a drift mine in NW. ¼ NE. ¼ sec. 21, T. 34 N., R. 55 E., 3 miles west of Antelope and 12 miles southeast of Plentywood.

Lignite bed.—Designated as "Richardson bed" by the United States Geological Survey. The bed lies about 800 feet above the base of the Fort Union formation of Tertiary age. Quality and thickness irregular. Dip, about 3½ feet per thousand southeastward.

The bed was measured and sampled at one point in the mine by C. M. Bauer, on August 12, 1912, as described below:

Section of lignite bed in Richardson mine.

Laboratory No.	14614	
Roof, carbonaceous shale.	*Ft.*	*in.*
Lignite	3	1
Shale, blue	[a]0	5
Lignite	5	2
Floor, brown shale.		
Thickness of bed	8	8
Thickness of lignite sampled	8	3

[a] Not included in sample.

The sample was collected 200 feet north of the opening on the east side of the entry, under 75 feet of cover.

Notes.—The lignite of this mine is representative of lignite mined in this part of Montana.

For a description of the geologic relations of this lignite bed, see U. S. Geol. Survey Bull. 541.

Bainville. Red Bank Mine.

Sample.—Lignite; Culbertson field; analysis No. 10898 (p. 55).

Mine.—Red Bank, an open-pit mine in sec. 10, T. 28 N., R. 59 E., 8 miles northeast of Bainville, which is the nearest station on the Great Northern Railway.

Lignite bed.—G, of the United States Geological Survey. Early Eocene age, Fort Union formation. Thickness, 5 feet 6 inches. The lignite is mined by stripping the clay and soil from the surface. The bed was sampled at one place in the pit by A. L. Beekly on September 1, 1910. The upper 5 feet of the bed was comparatively dry; the lower 6 inches was wet. The sample, which represents the full thickness of the bed, was taken at the face.

For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 347.

CULBERTSON. BRUEGGER MINE.

Sample.—Lignite; Culbertson field; analysis No. 10724. (p. 56.)

Mine.—Bruegger; sec. 8, T. 28 N., R. 56 E.; 3 miles north of Culbertson, on the Great Northern Railway.

Lignite bed.—E bed of the United States Geological Survey. Tertiary age, Fort Union formation. Thickness, 7 feet. Roof, a gray clay shale; floor, blue clay.

The lignite bed was measured and sampled at one point in the mine by A. L. Beekly on July 26, 1910. The sample was taken about 75 feet north of the mine opening and represents 7 feet of lignite, the thickness of the bed. The lower 2½ feet was hard lignite, the next 2½ feet was somewhat slacked and broken, and the upper 2 feet was hard lignite. The roof was a shaly clay, and the floor blue clay.

Notes.—In 1910 the mine was worked only in the winter and the output was small.

For analyses and descriptions of other samples of lignite from this mine, see Bull. 22, Bureau of Mines, 1913, pp. 135, 630.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 471, 1912, p. 345.

CULBERTSON. BUTTERFIELD MINE.

Sample.—Lignite; Culbertson field; analysis No. 10727 (p. 56).

Mine.—Butterfield, in sec. 3, T. 27 N., R. 56 E., 3¾ miles southeast of Culbertson, which is the nearest station on the Great Northern Railway.

Lignite bed.—DD bed of the United States Geological Survey. Tertiary age, Fort Union formation. Thickness, 6 feet. Roof, sandy shale; floor, clay.

The bed was sampled by A. L. Beekly on July 18, 1910. The sample was taken about 150 feet from the mouth of the entry, the upper 18 inches being left to support the roof, and represents only the lower 4½ feet of the bed.

Notes.—The lignite is hard and of fair quality. The woody structure is so evident that it is often difficult to determine whether it is "wood" or coal. The lignite is tough and elastic and requires a strong blasting powder. At the time of sampling the mine was small and produced only 5 or 6 wagon loads a day during the winter season.

For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 340.

CULBERTSON. DEMPSEY MINE.

Sample.—Lignite; Culbertson field; analysis No. 10725 (p. 56).

Mine.—Dempsey, in sec. 34, T. 28 N., R. 56 E., 3 miles southeast of Culbertson, which is the nearest station on the Great Northern Railway.

Lignite bed.—E bed of the United States Geological Survey. Tertiary age, Fort Union formation. Thickness, 6 feet 6 inches. Roof, sandy clay; floor, shaly clay. The lignite is free from partings and consists of alternating hard and soft layers; part of the bed is brown.

The bed was sampled at one point in the mine by A. L. Beekly on July 21, 1910. Sample 10725 was taken at the face, about 60 feet northeast of the mouth.

Notes.—The mine was not being worked at the time the sample was taken.

For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 345.

CULBERTSON. PROSPECT.

Sample.—Lignite; Culbertson field; analysis No. 10726 (p. 56).

Mine.—Prospect, in sec. 34, T. 28 N., R. 56 E., 3 miles southeast of Culbertson, on the Northern Pacific Railway.

Lignite bed.—F bed of the United States Geological Survey. Tertiary age, Fort Union formation. Thickness, 7 feet. Roof, sandy shale; floor, blue clay. The lignite is soft brown.

The bed was sampled at one point in the mine by A. L. Beekly on July 21, 1910. The sample was taken in the entry, about 50 feet from the mouth of the entry, and represents 7 feet of lignite, the thickness of the bed.

Notes.—This prospect is about one-half mile from the Peck mine. It was not being worked at the time the sample was taken.

For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 345.

FROID. ASTROPE MINE.

Sample.—Lignite; Culbertson field; analysis No. 11005 (p. 56).

Mine.—The Astrope, a local mine in sec. 15, T. 29 N., R. 55 E., 5½ miles southwest of Froid, which is the nearest station on the Bainville and Plentywood branch of the Great Northern Railway.

Lignite bed.—F of the United States Geological Survey, early Eocene age, Fort Union formation. Thickness, 6 feet. The upper 1 foot is soft, dirty lignite. The bed was sampled at one point in the mine by A. L. Beekly on September 14, 1910. The sample was taken in the mine 115 feet north of the mine mouth, and represents the lower 5 feet of the bed.

Notes.—At the time of sampling the output was 1 to 3 tons a day.

For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 348.

FROID. PROSPECT.

Sample.—Lignite; Culbertson field; analysis No. 11004 (p. 56).

Location.—A well in sec. 11, T. 29 N., R. 55 E., 3½ miles southwest of Froid, which is the nearest station on the Bainville and Plentywood branch of the Great Northern Railway.

Lignite bed.—F of the United States Geological Survey, early Eocene age, Fort Union formation. Thickness, 7 feet, 10 inches. Roof, clay; floor, clay. There were no partings in the coal.

The bed was sampled in the well by A. L. Beekly on September 14, 1910. The well, which was 6 feet in diameter, penetrated the bed at a depth of 30 feet below the surface.

For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 348.

MEDICINE LAKE. BELGON MINE.

Sample.—Lignite; Culbertson field; analysis No. 10899 (p. 56).

Mine.—Belgon, an open-pit mine in sec. 4, T. 31 N., R. 59 E., 15 miles east of Medicine Lake, which is the nearest station on the Bainville and Plentywood branch of the Great Northern Railway.

Lignite bed.—No name. Early Eocene age, Fort Union formation. Thickness, 10 feet.

The bed was measured and sampled at one point in the pit by A. L. Beekly on September 6, 1910.

The sample was taken from the fresh working face where the bed was 10 feet thick, and represents 7 feet 6 inches of hard, tough lignite, with a woody grain. There was 1 foot 6 inches of soft, brownish-black lignite above the part sampled and 1 foot of wet, muddy lignite below it. The roof was shale.

For a description of the geologic relations of the lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 350.

MEDICINE LAKE. COAL RIDGE MINE.

Sample.—Lignite; Culbertson field; analysis No. 11002 (p. 56).

Mine.—Coal Ridge, a drift mine in sec. 8, T. 34 N., R. 58 E., about 22 miles northeast of Medicine Lake, which is the nearest station on the Bainville and Plentywood branch of the Great Northern Railway.

Lignite bed.—Known as the Coal Ridge, early Eocene age, Fort Union formation. Thickness, 10 to 16 feet. The bed becomes thinner toward the west.

The bed was measured and sampled at one point in the mine by A. L. Beckly on September 23, 1910.

The sample was taken at the face of the entry, about 400 feet from the mine mouth, where the bed was 10 feet thick. The sample represents 6 feet 6 inches of lignite. The upper 2 feet are left for roof, and the lower 1 foot 6 inches for floor.

Notes.—The outcrop lignite was badly slacked and contained thin streaks of shale. The lignite at the outcrop was 14 feet thick.

At the time of sampling the mine was small, producing only about 3 tons a day.

For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 352.

MEDICINE LAKE. JONES MINE.

Sample.—Lignite; Culbertson field; analysis No. 11006 (p. 56).

Mine.—Jones, in sec. 30, T. 33 N., R. 56 E., 6 miles northeast of Medicine Lake, which is the nearest station on the Bainville and Plentywood branch of the Great Northern Railway.

Lignite bed.—Locally known as Jones. Early Eocene age, Fort Union formation. Thickness, about 7 feet. Above the coal is a sandy clay; in mining, 1 foot 6 inches of coal is left for roof.

The bed was sampled at one point in the mine by A. L. Beekly on September 19, 1910. The sample was taken 250 feet south of the entry mouth and represents 5 feet 6 inches of lignite. At the time of sampling the output was 3 to 5 tons a day.

For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 351.

MEDICINE LAKE. TED YOUNG MINE.

Sample.—Lignite; Culbertson field; analysis No. 11003 (p. 56).

Mine.—Ted Young, a drift mine in sec. 6, T. 31 N., R. 56 E., 2½ miles southeast of Medicine Lake, which is the nearest station on the Bainville and Plentywood branch of the Great Northern Railway.

Lignite bed.—Locally known as Young. Early Eocene age, Fort Union formation. Thickness, 3 feet 6 inches. The bed was measured and sampled at one point in the mine by A. L. Beekly on September 17, 1910. The sample was taken about 300 feet southeast of the entry mouth and represents 3 feet 6 inches, the thickness of the bed, of hard, black, clean lignite.

For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 349.

MONDAK. OPEN PIT MINE.

Sample.—Lignite; Culbertson field; analysis No. 10900 (p. 57).

Mine.—Open pit in sec. 19, T. 27 N., R. 59 E., 7 miles northwest of Mondak, on the Great Northern Railway, and 1½ miles from the railway.

Lignite bed.—G of the United States Geological Survey. Early Eocene age, Fort Union formation. Thickness, 4 feet 6 inches. The lignite is brownish black. The clay overburden, 10 feet thick, is removed in mining.

The bed was sampled at one place in the pit by A. L. Beekly on August 23, 1910. The upper 2 feet of the coal is more or less weathered and soft, and the sample does not include this part of the bed.

For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 471, 1912, p. 342.

PLENTYWOOD. PIERCE MINE.

Sample.—Lignite; Plentywood field; analysis No. 14670 (p. 57).

Mine.—Pierce; in SE. ¼ sec. 10, T. 35 N., R. 55 E., 2½ miles northeast of Plentywood.

Lignite bed.—Designated as "Richardson bed" by the United States Geological Survey. The bed lies about 800 feet above the base of the Fort Union formation of Tertiary age. At the point of sampling it is overlain by about 30 feet of Fort Union cover and 30 feet of glacial drift. Quality and thickness, irregular. Dip, about 3 feet per thousand southeastward.

The bed was measured and sampled at one point in the mine by C. M. Bauer on August 20, 1912, as described below:

Section of lignite bed in Pierce mine.

Laboratory No	14670	
Roof, carbonaceous shale.	*Ft.*	*in.*
Lignite	0	3
Shale	[a]0	8
Lignite	0	6
Shale	[a]0	3
Lignite, containing gypsum	2	0
Clay	[a]0	7
Lignite	3	9
Floor shale.		
Thickness of bed	8	0
Thickness of lignite sampled	6	6

[a] Excluded from sample.

The above section (sample 14670) was measured in the mine, 250 feet northwest of the opening.

Notes.—For a description of the geologic relations of this lignite bed see U. S. Geol. Survey Bull. 541.

NEVADA.

ESMERALDA COUNTY.

COALDALE. DARMS MINE.

Sample.—Bituminous coal; Coaldale field; analysis No. 13978 (p. 57).

Mine.—Darms, a slope mine in NE. ¼ sec. 33, T. 2 N., R. 37 E.; 3½ miles southeast of Coaldale, on the Tonopah & Goldfield Railroad.

Coal bed.—C. Tertiary (Eocene or Miocene) age. Thickness, variable. Dip variable, being 60° NE. at the outcrop, 77° at 245 feet down the slope, and 10° at 280 feet. Strike, N. 53° W.

The bed was measured and sampled by J. H. Hance on March 7, 1912. Sample 13978 was taken in a drift off the slope, 300 feet from the mouth of the slope and 20 feet from the slope. The sample represents 7 feet of impure coal, the thickness of the bed.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 531, 1913, p. 321.

COALDALE. NEVADA MINE.

Sample.—Bituminous coal; Coaldale field; analyses Nos. 13979, 13980, and 14409 (p. 57).

Mine.—Nevada, a slope mine in S. ½ of SE. ¼ sec. 29, T. 2 N., R. 37 E., 3½ miles southeast of Coaldale, on the Tonopah & Goldfield Railroad.

Coal bed.—C. Tertiary (Eocene or Miocene) age; dip variable. The bed is cut off to the south by a fault.

The bed was measured and sampled at two points in the mine by J. H. Hance on March 8, 1912.

Notes.—Sample 13979 was taken at a point in the slope 150 feet from the mouth and represents 9 feet of impure coal, the entire thickness of the bed. Sample dry.

Sample 13980 was taken at a place in the mine 100 feet from the mouth and represents 8 feet of impure coal, the entire thickness of the bed.

Sample 14409 was taken from a block of coal representing a bench 12 inches thick in the mine. This block was sent by freight to Washington and the sample was cut by M. R. Campbell on July 17, 1912. The sample is supposed to represent the best coal in the bed.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 531, 1913, p. 320.

NEW MEXICO.

BERNALILLO COUNTY.

ALBUQUERQUE. HOLMES MINE.

Sample.—Bituminous coal; Tijeras field; analysis No. 12650 (p. 57).

Mine.—Holmes; a prospect drift entry in SW. ¼ sec. 6, T. 10 N., R. 6 E., about 25 miles east of Albuquerque.

Coal bed.—Not named. Cretaceous age; Mesaverde formation. Thickness, 6 inches to 2 feet 3 inches. There is shale above and below the coal. The coal is impure and badly crushed.

The bed was measured and sampled by W. T. Lee on July 17, 1911.

The sample was taken 300 feet from the mouth of the entry from a fresh face where the coal was 2 feet 3 inches thick. The same bed in other parts of the entry was only 6 inches thick. The differences were probably due to crushing.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 471, 1912, p. 576.

COLFAX COUNTY.

DAWSON. DAWSON NO. 2 MINE.

Sample.—Bituminous (coking) coal; Raton field; analyses Nos. 12233, 12234, and 12235 (p. 57).

Mine.—Dawson No. 2, a drift mine in the Dawson district. The Dawson mines are in secs. 1, 2, 11, and 12, T. 29 N., and secs. 35 and 36, T. 28 N., R. 20 E., at Dawson, on the El Paso & Southwestern Railroad.

Coal bed.—"Raton." Cretaceous age, Vermejo formation. Average thickness, 6 feet; dip, 1° northwest; cleat, east and west. Roof, sandstone; floor, usually smooth clay and shale. Cover at points of sampling, 250 feet.

The bed was measured and sampled at two points in the mine by J. C. Roberts on May 17, 1911, as described below:

Sections of coal bed in Dawson No. 2 mine.

Section	A		B	
Laboratory No.	12233		12234	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*
Coal, bony	[a]1	6	..	..
Coal	2	4	0	6
Coal, bony	0	2	0	5
Coal	1	2	7	4
Coal, bony	0	½	..	..
Coal	2	9½	..	..
Coal, bony	[a]1	6	..	..
Floor, bony coal and shale.				
Thickness of bed	9	6	8	3
Thickness of coal sampled	6	6	8	3

[a] Not included in sample.

Section A (sample 12233) was measured at the face of the fifth north, 6,700 feet northeast of the "high line" entrance and represents a full face sample.

Section B (sample 12234) was measured at the face of the thirteenth east, 6,500 feet from the "high line" entrance.

Notes.—There are 5 mines at Dawson. At the time of sampling the mines had the following capacities: No. 1, 1,500 tons a day; No. 2, 2,000; No. 4, 1,400; and No. 5, 2,000 tons. The room-and-pillar method of mining is employed. The coal was shot down with "forty per cent" dynamite. None of the coal was shipped as run-of-mine. About 2,000 tons a day was sent to the screens and about 40 per cent passed through a shaking screen with 2-inch and 4-inch openings; pickers were employed. The screenings were coked; the coke ovens had a daily capacity of 1,600 tons. There were 5 loading tracks with a capacity of 200 empty and 200 loaded cars.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 137, 640.

GARDINER. GARDINER NO. 1 MINE.

Sample.—Bituminous coal; Raton field; analysis No. 14795 (p. 57).

Mine.—Gardiner No. 1, a (new) drift mine in the Blossburg district, at Gardiner, one-half mile southeast of Blossburg.

Coal bed.—Raton. Cretaceous age, Vermejo formation. The bed is regular in thickness, but its value is diminished in some places by crushing and other movements of the inclosing rocks. Roof, shale; floor, shale.

The bed was measured and sampled at one point in the mine by W. T. Lee on September 27, 1912, as described below:

Section of coal bed in Gardiner No. 1 mine.

Laboratory No.	14795	
Roof, shale.	*Ft.*	*in.*
Coal, bony	[a]0	7
Coal	5	5
Floor, shale.		
Thickness of bed	6	0
Thickness of coal sampled	5	5

[a] Not included in sample.

Notes.—The sample was collected from a fresh face in room 6 off first west entry off the main entry, 400 feet from the outcrop. At the time of sampling the mine was doing development work and was shipping only 100 tons a day.

KOEHLER. KOEHLER No. 1 MINE.

Sample.—Bituminous (coking) coal; Raton field; analyses Nos. 12335, 12336, 12337, and 14796 (p. 58).

Mine.—Koehler No. 1, a drift mine in the Koehler district, T. 29 N., R. 22 E., at Koehler, on the St. Louis, Rocky Mountain & Pacific Railway.

Coal bed.—Raton. Cretaceous age, Vermejo formation. Average thickness, 9 feet, regular; dip 1° west. The roof is shale, bony coal, or sandstone, according to the locality. In most places where conglomeratic sandstone rests on the coal the bed has been partly eroded and is too thin to be mined. Floor, shale; cover, 450 to 500 feet.

The bed was measured and sampled at three points in the mine by J. C. Roberts on May 28, 1911, and at one point by W. T. Lee on September 27, 1912, as described below:

Sections of coal bed in Koehler No. 1 mine.

Section	A	B	C	D
Laboratory No	12335	12336	12337	14796
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal, bony	[a]2 0	[a]2 0	.. ..	[a]2 0
Coal	6 0	6 2	5 9	6 3
Coal (poor)	[a]1 0	.. ..	.. ..	.. ..
Floor, shale.				
Thickness of bed	9 0	8 2	5 9	8 3
Thickness of coal sampled	6 0	6 2	5 9	6 3

[a] Not included in sample.

Section A (sample 12335) was measured as the face of room 20, off seventh east entry, 4,500 feet southeast of the mouth of the main entry.

Section B (sample 12336) was measured at the face of eighth west entry, 4,300 feet southeast of the mouth of the main entry.

Section C (sample 12337) was measured in room 20, off seventh east entry, 4,200 feet southeast of the mouth of the main entry.

Section D (sample 14796) was measured at the face of ninth west entry, 4,900 feet southwest of the main opening in Prairie Crow Canyon.

Notes.—There are three mines at Koehler. The room-and-pillar method of mining is employed. At the time of sampling the mines had the following capacity: No. 1, 1,000 tons a day; No. 2, 1,400 tons; and No. 3, 400 tons. From 300 to 350 men were employed. There was enough coal to maintain the above output for many years. Ten per cent of the coal was shipped as run-of-mine. The washer had a capacity of 1,200 tons a day, the coke ovens 700 tons, and the storage bins 800 tons. There were four loading tracks with a capacity of 60 empty and 80 loaded cars.

SUGARITE. SUGARITE No. 1 AND No. 2 MINES.

Sample.—Bituminous coal; Raton field; analyses Nos. 14791 and 14792 (p. 58).

Mines.—Sugarite No. 1 in NE. ¼ NE. ¼ sec. 9, T. 31 N., R. 24 E.; and Sugarite No. 2 in NE. ¼ SW. ¼ sec. 3, T. 31 N., R. 24 E. (private survey); drift mines at Sugarite.

Coal bed.—Sugarite. Cretaceous or Tertiary age, Raton formation. Roof, shale, with thin seams of coal; floor, shale.

The bed was measured and sampled at one point in No. 1 mine by W. T. Lee on September 27, 1912, as described below.

Section of coal bed in Sugarite No. 1 mine.

Laboratory No	14791
Roof, shale, with thin seams of coal.	*Ft. in.*
Coal	[a]0 4
Shale	[a]0 1½
Coal	5 1
Floor, shale.	
Thickness of bed	5 6½
Thickness of coal sampled	5 1

[a] Not included in sample.

The above section (sample 14791) was measured in the entry, 1,500 feet southwest of the mine mouth.

The bed was measured and sampled at one point in No. 2 mine by W. T. Lee on September 27, 1912, as described below:

Section of coal bed in Sugarite No. 2 mine.

Laboratory No	14792
Shale, with thin seams of coal.	*Ft. in.*
Coal	[a]0 6
Shale	[a]0 2
Coal	3 5
Bone	[a]0 2
Coal	1 4
Shale.	
Thickness of bed	5 7
Thickness of coal sampled	4 9

[a] Not included in sample.

The above section (sample 14792) was measured in the entry, 1,200 feet northeast of the mine mouth.

Notes.—At the time the samples were taken the mines were new, and all the coal produced was from the main entries.

YANKEE. YANKEE NO. 3 MINE.

Sample.—Bituminous (noncoking) coal; Raton field; analyses Nos. 13365, 13366, and 13367 (p. 58).

Mine.—Yankee No. 3, a slope mine at Yankee, on the Santa Fe, Raton & Eastern Railroad with connections to the Atchison, Topeka & Santa Fe Railway and the St. Louis, Rocky Mountain & Pacific Railway.

Coal bed.—Yankee. Cretaceous or Tertiary age, Raton formation. Average thickness, 5 feet 6 inches; dip, 4 per cent northwest; cleat, east and west. The roof is a soft black shale which is treacherous; above the shale is a sandstone cap rock. Floor, soft smooth fire clay. Particles of the roof did not become mixed with the coal in mining but particles of the floor did. Cover at points of sampling, 250 to 300 feet.

The bed was measured and sampled at two points in the mine by J. C. Roberts on February 8, 1912, as described below:

Sections of coal bed in Yankee No. 3 mine, near Yankee.

Section	A	B
Laboratory No	13365	13366
Roof, shale.	*Ft. in.*	*Ft. in.*
Coal	0 5	0 5
Shale	[a]0 1½	[a]0 4
Coal	1 0	1 0
Shale	[a]0 1	[a]0 1½
Coal	0 7	0 7
Shale	[a]1 0	[a]1 3
Coal	2 7	2 7
Floor, shale.		
Thickness of bed	5 9½	6 3½
Thickness of coal sampled	4 7	4 7

[a] Not included in sample.

Section A (sample 13365) was measured at the face of room 2, off tenth west entry 10.

Section B (sample 13366) was measured at the face of fifth south entry.

A composite sample was made by mixing face samples 13365 and 13366. The results of an ultimate analysis of this sample are shown under laboratory No. 13367.

Notes.—At the time of sampling, the coal was undercut by hand; the cuttings were not loaded with the coal. Permissible explosives were used for breaking down the coal and for brushing the roof and floor. All the output was shipped as run-of-mine. The tipple was equipped with a bar screen 16 feet long and 3 feet wide with 3-inch openings between the bars; a shaking screen 10 feet long by 8 feet wide, with ¾-inch, 2-inch, and 3-inch holes; and a revolving screen 16 feet long with ¾-inch openings. Pickers were employed at the conveyor belt and on the car. The lumps were medium large and of good appearance. There were four loading tracks with a capacity of 35 empty and 35 loaded cars. The daily output of the mine was 200 tons; the intent was to increase it to 2,500 tons. The mine had a probable life of 10 years.

For analysis and description of another sample of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 139, 645.

LINCOLN COUNTY.

WHITE OAKS. OLD ABE MINE.

Sample.—Bituminous coal; White Oaks field; analysis No. 15053 (p. 59).

Mine.—Old Abe, a slope mine in NW. ¼ sec. 5, T. 7 S., R. 13 E., 2½ miles southeast of White Oaks.

Coal bed.—Old Abe. Post-Laramie (?) age. Thickness, variable; dip, 20° west. The bed was measured and sampled at one point in the mine by C. H. Wegemann on November 3, 1912, as described below:

Section of coal bed in Old Abe mine.

Laboratory No.	15053	
Roof, sandstone.	*Ft.*	*in.*
Coal	0	2
Bone	0	1
Coal	1	½
Bone	0	¾
Coal	0	10¾
Bone	0	¼
Coal	0	4
Coal, poor	0	1
Coal	1	4
Floor, shale.		
Thickness of bed	4	¼
Thickness of coal sampled	4	¼

The above section was measured in the main slope, 300 feet from the slope mouth. At the time of sampling a slope had been run on the dip of the bed (20° west) and side entries driven from it, the rooms being driven up the rise from the entries.

For analyses and descriptions of another sample of coal from this mine, see Bull. 22, Bureau of Mines, 1913, pp. 139, 646.

WHITE OAKS. WILD CAT MINE.

Sample.—Bituminous coal; White Oaks field; analysis No. 15054 (p. 59).

Mine.—Wild Cat, a slope mine in SW. ¼ sec. 32, T. 6 S., R. 13 E., 2 miles southeast of White Oaks.

Coal bed.—Not named. Post-Laramie (?) age. Thickness, variable; dip, 25° west. The bed was measured and sampled at one point in the mine by C. H. Wegemann, on November 3, 1912, as shown below:

Section of bed in Wild Cat mine.

Laboratory No.	15054	
Roof, black shale.	*Ft.*	*in.*
Bone	[a]0	3½
Coal	0	8¼
Bone	0	1¼
Coal	0	11
Coal, bony	0	1
Floor, black shale.		
Thickness of bed	2	1
Thickness of coal sampled	1	9½

[a] Not included in sample.

The above section (sample 15054) was measured near the foot of the main slope. At the time of sampling a slope about 240 feet in length had been run on the dip of the bed (25° west) and entries driven from it, the rooms being driven up the rise.

M'KINLEY COUNTY.

BLACKROCK. ZUNI INDIAN SCHOOL MINE.

Sample.—Subbituminous coal; Durango-Gallup field; analysis No. 15032 (p. 59).

Mine.—Zuni Indian School, a drift mine in sec. 6, T. 11 N., R. 17 W., 10 miles northeast of Blackrock.

Coal bed.—Not named. Cretaceous age, in the Benton group, below the Mesaverde formation. The bed was measured and sampled at one point in the mine by D. E. Winchester, on October 11, 1912, as described below:

Section of coal bed in Zuni Indian School mine.

Laboratory No.	15032	
Roof, shale.	*Ft.*	*in.*
Bone	[a]0	2
Coal	1	10
Bone	[a]0	2
Coal	1	0
Floor, shale.		
Thickness of bed	3	2
Thickness of coal sampled	2	10

[a] Not included in sample.

Note.—The sample was taken in room 2, west of the main entry.

SANTA FE COUNTY.

MADRID. ANTHRACITE NO. 4 MINE.

Sample.—Anthracite coal; Cerrillos field; analysis No. 14886 (p. 59).

Mine.—Anthracite No. 4, a slope mine at Madrid, on the Ortiz land grant.

Coal bed.—White Ash. Cretaceous age; Mesaverde formation. Thickness, relatively uniform; dip, about 15° east. The roof is shale in most places, in some places it is formed by an overlying sill of intrusive rock, which has locally metamorphosed the coal. The floor is shale.

The bed was measured and sampled at one point in the mine by W. T. Lee on October 10, 1912.

The sample was collected from a working face 1,500 feet southeast of the mouth of the main entry, at a point where the coal was 2 feet 9 inches thick.

Note.—The output at the time the sample was taken was 150 tons a day. The coal was used mainly for domestic purposes.

For a description of the geologic relations of this coal bed see U. S. Geological Survey Bull. 531, 1913, p. 286.

MADRID. BLACKSMITH MINE.

Sample.—Bituminous coal; Cerrillos field; analysis No. 14884 (p. 59).

Mine.—Blacksmith, a drift mine at Madrid, on the Ortiz land grant.

Coal bed.—Peacock (?). Cretaceous age; Mesaverde formation.

The bed was measured and sampled at one point in the mine by W. T. Lee on October 10, 1912, as described below:

Section of coal bed in Blacksmith mine.

Laboratory No.	14884	
Roof, shale.	*Ft.*	*in.*
Coal	[a]0	6
Shale	[a]2	2
Coal	0	9
Shale	[a]0	3
Coal	1	7
Floor, shale.		
Thickness of bed	5	3
Thickness of coal sampled	2	4

[a] Not included in sample.

Notes.—The sample was collected from a fresh face in the mine, 300 feet from the mouth of the mine. The coal at this point, as in general throughout the mine, is crushed by movements of the containing rocks.

For a description of the geologic relations of this coal bed see U. S. Geological Survey Bull. 531, 1913, p. 297.

MADRID. HOLEN MINE.

Sample.—Bituminous coal; Cerrillos field; analysis No. 14885 (p. 59).

Mine.—Holen, a slope mine at Madrid, on the Ortiz land grant.

Coal bed.—Cook & White. Cretaceous age; Mesaverde formation. The roof and floor are shale.

The bed was measured and sampled at one point in the mine by W. T. Lee on October 9, 1912, as described below:

Section of coal bed in Holen mine.

Laboratory No.	14885	
Roof, shale.	*Ft.*	*in.*
Bone	[a]0	2
Coal	3	3
Floor, shale.		
Thickness of bed	3	5
Thickness of coal sampled	3	3

[a] Not included in sample.

The sample was taken from a working face 1,300 feet east of the mine mouth.

Notes.—The coal near the surface does not coke, but a few hundred feet from the surface it changes to a coking coal. At the time of sampling the output of the mine was 100 tons a day. The coal was used mainly for domestic fuel.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 531, 1913, p. 306.

MADRID. PEACOCK PROSPECT.

Sample.—Bituminous coal; Cerrillos field; analysis No. 14887 (p. 59).

Mine.—Peacock, a prospect slope entry at Madrid, on the Ortiz land grant.

Coal bed.—Peacock. Cretaceous age, Mesaverde formation. Both roof and floor are bony coal.

The bed was measured and sampled at one point in the mine by W. T. Lee on October 10, 1912.

The sample was taken in the entry 400 feet northeast of the mouth of the entry from a face freshly cleared for the purpose of sampling. The sample represents 2 feet 4 inches of coal. There was bony coal above and below the part sampled.

Notes.—The prospect was not being worked at the time of sampling.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 531, 1913, p. 297.

NORTH DAKOTA.

ADAMS COUNTY.

HAYNES. NIPPER & MONROE MINE.

Sample.—Lignite; Cannonball River field; analysis No. 14542 (p. 59).

Mine.—Nipper & Monroe, a drift mine in sec. 16, T. 129 N., R. 94 W., 3½ miles northeast of Haynes.

Lignite bed.—Haynes. Tertiary (Eocene) age, Fort Union formation. Average thickness reported, 12 feet.

The bed was sampled at one point in the mine by E. R. Lloyd on July 30, 1912. The part sampled was 8 feet 3 inches thick. The top of the bed had been left for roof because the overlying shale was not strong.

The sample was collected 630 feet east of the mouth of the entry.

For a description of the geologic relations of this bed see U. S. Geol. Survey Bull. 541.

HAYNES. WILLIAM PINKHAM MINE.

Sample.—Lignite; Cannonball River field; analysis No. 14544 (p. 59).

Mine.—William Pinkham, in sec. 36, T. 130 N., R. 94 W., about 9 miles northwest of Haynes.

Lignite bed.—Haynes. Tertiary (Eocene) age, Fort Union formation. Thickness, about 12 feet.

The bed was sampled at one point in the mine by E. R. Lloyd on July 30, 1912. The part sampled was 8 feet 10 inches thick and uniform in quality. The top of the bed had been left for roof because the overlying shale was weak.

The sample was taken 225 feet south of the mouth of the mine.

For a description of the geologic relations of this bed see U. S. Geol. Survey Bull. 541.

BOWMAN COUNTY.

AMOR. DURKIN PROSPECT.

Sample.—Lignite; Bowman County field; analysis No. 14857 (p. 59).

Location.—Open pit, known as the Durkin prospect, 2 miles southeast of Amor post office in SW. ¼ sec. 34, T. 130 N., R. 103 W., and 12 miles southwest of Bowman.

Lignite bed.—This bed is included in the Ludlow lignitic member of the Lance formation, Cretaceous or Tertiary age, and is designated as the T Cross bed from its best exposure, being at the T Cross ranch on Bacon Creek in sec. 20, T. 133 N., R. 104 W., in Billings County, where it is 24 feet thick. Its average thickness in Bowman County is about 5 feet, ranging from 3 feet 2 inches to 10 feet. The bed lies nearly flat, dipping only slightly to the northeast.

The bed was measured and sampled July 31, 1912, by C. J. Hares, as shown below:

Section of lignite in outcrop 2 miles southeast of Amor.

Laboratory No.	14857	
Roof, sandstone.	*Ft.*	*in.*
Lignite, dirty and badly weathered	[a]3	7
Lignite, dirty	[a]0	7
Lignite, fair	0	9
Lignite, good, but with considerable marcasite	[a]0	2
Lignite, excellent	1	10½
Lignite, good, under water	[a]1	8
Floor, not stated.		
Thickness of bed	8	7½
Thickness of lignite sampled	2	7½

[a] Not included in sample.

Notes.—There was 1 foot 6 inches of soft sandstone, overlain by 5 feet of shale and soil, above the lignite. The lignite is mined by stripping. At the time the sample was collected no lignite had been removed for some time, a face was cleaned and a fairly fresh sample obtained. The lignite was used wholly for local purposes.

SCRANTON. SCRANTON MINE.

Sample.—Lignite; Bowman County field; analysis No. 14485 (p. 59).

Mine.—Scranton, a drift mine in SW. ¼ sec. 24, T. 131 N., R. 100 W., at Scranton, on the Chicago, Milwaukee & St. Paul Railroad.

Lignite bed.—Probably the Harmon bed of Smith and Leonard (see U. S. Geol. Survey Bull. 341, p. 24) and the same one as sampled on Sand Creek (see U. S. Geol. Survey Bull. 285, p. 324) where it is 31 feet thick. About 200 feet above the base of the Fort Union formation, Tertiary age. Thickness, 19 to 23 feet, average 20½ feet. The bed lies nearly flat. It is by far the most important, thickest, and most extensive bed in Bowman and Billings counties.

The bed was measured and sampled at one point in the mine on June 30, 1912, by E. G. Woodruff and C. J. Hares, as shown below:

Section of lignite bed in Scranton mine.

Laboratory No.	14485	
Clay.	*Ft.*	*in.*
Lignite	[a]5	0
Lignite, impure	[a]0	7
Lignite	6	0
Shale, brown, carbonaceous	[a]0	1½
Lignite	[a]0	7
Lignite	[a]8	0
Thickness of bed	20	3½
Thickness of lignite sampled	6	0

[a] Not included in sample.

The sample was taken at the face of the main east entry, off the main entry, about 500 feet from the main entry and 1,000 feet from the mouth of the main entry. The upper 5 feet of the bed is left for roof and the lower 8 feet for floor.

Notes.—The lignite from this mine is tough and woody but readily slacks upon exposure to air and sunlight. For that reason the lignite will not withstand long shipment. At the time of sampling it was used at points along the Chicago, Milwaukee & St. Paul Railroad, in the brick yards at Scranton, and by farmers.

For results of briquetting tests of this lignite see Bull. 14, Bureau of Mines, 1912, pp. 31, 32.

For analyses and descriptions of other samples of lignite from this mine see Bull. 22, Bureau of Mines, 1913, pp. 142, 658.

MORTON COUNTY.

LEITH. JONES MINE.

Sample.—Lignite; Cannonball River field; analysis No. 14729 (p. 60).

Mine.—Jones, a shaft mine in sec. 12, T. 133 N., R. 88 W., 1½ miles west of Leith. Cover, 42 feet.

Lignite bed.—Haynes (?). Cretaceous age, Fort Union formation. The bed is reported to be 8 feet 6 inches thick and to have a shale roof. Only 5 feet 6 inches of the bottom of the bed is being mined, the upper 3 feet being left for roof. The lignite is uniform in quality, from dull to bright luster, and contains thin partings of mineral charcoal. There is also a considerable amount of pyrite in nodules which are easily separable from the lignite.

The bed was sampled at one point in the mine by E. R. Lloyd and C. E. Lesher on September 7, 1912. The sample was taken about 75 feet southwest of the foot of the shaft.

For a description of the geologic relations of the lignite bed see U. S. Geol. Survey Bull. 541.

WARD COUNTY.

PLAZA. PROSPECT.

Sample.—Lignite; analysis No. 11294 (p. 60).

Mine.—Prospect, in sec. 17, T. 152 N., R. 92 W., 25 miles west of Plaza, on the Minneapolis, St. Paul & Sault Ste. Marie Railroad.

Lignite bed.—Known as No. 3. Tertiary age, Fort Union formation. Thickness, 4 feet 11 inches. Roof, shale 6 inches thick; floor, clay. The bed was measured and sampled by M. A. Pishel on October 27, 1910. The bed was 4 feet 11 inches thick. The sample represented the lower 3 feet 8 inches, the upper 1 foot 8 inches being dirty coal. There was shale above the coal and clay below it.

WILLIAMS COUNTY.

AVOCA. BRUEGGER MINE.

Sample.—Lignite; Williston field; analysis No. 12587 (p. 60).

Mine.—Bruegger; in the NW. ¼ SE. ¼ sec. 3, T. 154 N., R. 100 W., one-third mile northeast of Avoca, on the Great Northern Railway.

Lignite bed.—C bed. Tertiary (early Eocene) age, Fort Union formation.

The bed was measured and sampled at one point in the mine by F. A. Herald on September 5, 1911, as described below:

Section of lignite bed in the Bruegger mine.

Laboratory No.	12587	
	Ft.	*in.*
Lignite	[a] 3	4
Lignite	[a] 5	6
Clay	[a] 0	4
Lignite	1	10
Thickness of bed	11	0
Thickness of lignite sampled	5	6

[a] Not included in sample.

Note.—The section was measured 50 feet west of the end of the main entry and 1,225 feet from the mine mouth. The sample was wet.

For a description of the geologic relations of this bed, see U. S. Geol. Survey Bull. 531, 1913, p. 122.

TRENTON. GELTZ MINE.

Sample.—Lignite; Williston field; analysis No. 12411 (p. 60).

Mine.—Geltz, in the NW. ¼ sec. 27, T. 154 N., R. 102 W., 6 miles northeast of Trenton, on the Great Northern Railway.

Lignite bed.—No name. Tertiary (early Eocene) age, Fort Union formation. The bed was measured and sampled by F. A. Herald on June 30, 1911, as described below:

Section of lignite bed in the Geltz mine.

Laboratory No	12411	
Roof, yellow clay and shale.	*Ft.*	*in.*
Lignite, hard, clean	3	4
Clay, gray	[a] 0	5
Lignite	1	9
Floor, not stated.		
Thickness of bed	5	6
Thickness of lignite sampled	5	1

[a] Not included in sample.

Notes.—The sample was collected at the end of the main entry, 150 feet from the mine mouth. The sample represents dry lignite. The mine was worked intermittently; the lignite was used for local purposes.

For a description of the geologic relations of this bed, see U. S. Geol. Survey Bull. 531, 1913, p. 128.

WILLISTON. POWELL MINE.

Sample.—Lignite; Williston field; analysis No. 12588 (p. 60).

Mine.—Powell, in NW. ¼ of SE. ¼ sec. 33, T. 154 N., R. 100 W., 3½ miles southeast of Williston, on the Great Northern Railway.

Lignite bed.—C. Tertiary (early Eocene) age, Fort Union formation.

The bed was measured and sampled by F. A. Herald on September 6, 1911.

The sample represents the lower 6 feet 6 inches of the bed, which at this point was 10 feet thick.

Notes.—The sample was taken 50 feet north of the main entry and 900 feet northeast of the mine mouth. The lignite was dry. The daily output was 30 tons in the summer and 50 tons in the winter.

For a description of the geologic relations of this bed, see U. S. Geol. Survey Bull. 531, 1913, p. 122.

WILLISTON. U. S. RECLAMATION SERVICE MINE.

Sample.—Lignite; Williston field; analysis No. 12533 (p. 60).

Mine.—U. S. Reclamation Service; SE. ¼ NE. ¼ sec. 7, T. 154 N., R. 100 W.; 3 miles northeast of Williston, on the Great Northern Railway.

Lignite bed.—B. Tertiary (early Eocene) age, Fort Union formation. Thickness, 10 feet to 10 feet 6 inches. The bed was measured and sampled by F. A. Herald on August 16, 1911, the sample representing the bottom 8 feet of the bed, which is here 10 feet 3 inches thick.

Notes.—The sample was taken from William Spangler's room, 50 feet north of the main entry and 1,225 feet east of the mine mouth, and represents dry lignite. In 1911 the mine was operated only during the irrigation season. The daily output averaged 90 tons.

For a description of the geologic relations of this bed, see U. S. Geol. Survey Bull. 531, 1913, p. 121.

OHIO.

JEFFERSON COUNTY.

AMSTERDAM. AMSTERDAM MINE.

Sample.—Bituminous coal; Ohio field; analyses Nos. 10533, 15388, 15389, and 15390 (p. 61).

Mine.—Amsterdam, a shaft mine in sec. 18, T. 11 N., R. 4 W., near Amsterdam, on the Lake Erie, Alliance & Wheeling Railroad.

Coal bed.—Lower Freeport (?). Carboniferous age, Allegheny formation. Thickness, excluding bony coal at top of bed, 4 to 4½ feet; fairly uniform. The bed is overlain by shale 12 feet thick; above the shale is another coal bed of variable thickness. The shale roof is very poor; most of the rooms fall in before being worked out. The floor is an underclay, which is taken up in the haulage ways.

The bed was measured and sampled at three points in the mine by D. D. Condit on December 27, 1912, as described below:

Sections of coal bed in Amsterdam mine.

Section	A		B		C	
Laboratory No	15388		15389		15390	
Roof, shale or bony coal.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, bony	[a] 1	3	[a] 1	2	[a] 1	2
Coal	1	11	1	7½	1	6½
Bone	[a] 0	2½	[a] 0	3¼	[a] 0	3
Coal	1	10	1	8½	1	11
Coal, impure	[a] 0	5	[a] 0	5	[a] 0	5
Floor, shale.						
Thickness of bed	5	7½	5	2¼	5	3½
Thickness of coal sampled	3	9	3	4	3	5½

[a] Not included in sample.

Section A (sample 15388) was measured in room 4, off entry 4, east section, 1,000 feet northeast of the shaft.

Section B (sample 15389) was measured in room 15, off west entry 9, section 2 north, 4,000 feet northwest of the shaft.

Section C (sample 15390) was measured in section 3 south, west entry 8, 4,500 feet southwest of the shaft.

The bed was measured and sampled at one point in the mine by J. W. Paul on May 3, 1910.

The sample (No. 10533) was taken at the center of the face of the face entry, where the bed was 5 feet 2 inches thick, and represented the lower 4 feet 1 inch, all clean coal. There was 13 inches of bony coal above the part sampled.

Notes.—The shaft is 270 feet deep to the top of the coal. The coal is mined by the room-and-pillar method. At the time of sampling the coal was undercut by electric cutting machines.

AMSTERDAM. EASTERN OHIO MINE.

Sample.—Bituminous coal; Ohio field; analyses Nos. 15391, 15392, and 15393 (p. 61).

Mine.—Eastern Ohio, a slope mine in NE. ¼ sec. 8, T. 12 N., R. 4 W., on the Lake Erie, Alliance & Wheeling Railroad, halfway between Amsterdam and Bergholz.

Coal bed.—Lower Freeport (?). Carboniferous age, Allegheny formation. Roof, dark sandy shale, fairly firm. A little below the middle of the bed is a thin, persistent layer of bony coal. The coal is hard and tough.

The bed was measured and sampled at three points in the mine by D. D. Condit on December 28, 1912, as described below:

Sections of coal bed in Eastern Ohio mine.

Section	A		B		C	
Laboratory No	15391		15392		15393	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, impure	[a] 0	4	[a] 0	4	[a] 0	3
Coal	2	5	2	9	3	1
Bone	[a] 0	2	[a] 0	3	[a] 0	2½
Coal	2	3	2	0	1	10
Coal, impure	[a] 0	2	..	..	..	..
Floor, clay and shale.						
Thickness of bed	5	4	5	4	5	4½
Thickness of coal sampled	4	8	4	9	4	11

[a] Not included in sample.

Section A (sample 15391) was measured in room 11, off west butt entry 12, 3,000 feet west of the mouth of the slope.

Section B (sample 15392) was measured at west entry 13, off the south face entry.

Section C (sample 15393) was measured in left butt entry 12, off the north face entry, 2,700 feet northeast of the mouth of the slope.

AMSTERDAM. ELIZABETH MINE.

Sample.—Bituminous coal; Ohio field; analyses numbers 15440, 15441, and 15443 (p. 61).

Mine.—Elizabeth, a shaft mine in SE. ¼ sec. 7, T. 12 N., R. 4 W., 2 miles east of Amsterdam, on a branch of the Lake Erie, Alliance & Wheeling Railroad.

Coal bed.—Probably the Lower Freeport. Carboniferous age, Allegheny formation. Roof, shale; floor, clay.

The bed was measured and sampled at three places in the mine by D. D. Condit on December 30, 1912, as described below:

Sections of coal bed in Elizabeth mine.

Section	A		B		C	
Laboratory No	15440		15441		15443	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, bony	..	..	[a] 0	7	[a] 0	4½
Coal, impure	0	5	0	7	0	6
Bone	[a] 0	2	[a] 0	2½	[a] 0	1
Coal	1	9	1	9	1	7
Bone	[a] 0	3½	[a] 0	3	[a] 0	3½
Coal	1	7	1	9	1	9½
Coal, impure	[a] 0	3	[a] 0	4	..	..
Floor, clay.						
Thickness of bed	4	5½	5	5½	4	7½
Thickness of coal sampled	3	9	4	1	3	10½

[a] Not included in sample.

Section A (sample 15440) was measured in room 22, off west entry 3, 2,600 feet northwest of the shaft.

Section B (sample 15441) was measured in room 33, off the second south face entry, 2,400 feet west of the shaft.

Section C (sample 15443) was measured in room 6, off west entry 9, 2,600 feet northeast of the shaft.

Notes.—The coal is hard and tough and breaks with a conchoidal fracture. The impure bony coal at the top and the two bone layers in the body of the bed are persistent and vary considerably in thickness from place to place. Pyrite bands are plentiful. The shale roof requires little timbering. Most of the mine workings were unusually dry. The equipment of the mine was modern. The daily output of the mine (run-of-mine) was reported at about 1,000 tons at the time of sampling.

BRILLIANT. GOUCHER No. 2 MINE.

Sample.—Bituminous coal; Ohio field; analyses Nos. 15563 and 15564 (p. 62).

Mine.—Goucher No. 2, a drift mine, in SE. ¼ sec. 6, T. 5 N., R. 2 W., 1 mile west of Brilliant, on Cleveland & Pittsburg division of the Pennsylvania Railroad.

Coal bed.—Pittsburgh or No. 8. Carboniferous age, Monongahela formation. Thickness fairly uniform; at this mine about 5 feet. The bed lies nearly flat.

The bed was measured and sampled at two points in the mine by D. D. Condit on January 4, 1913, as described below:

Sections of coal bed in Goucher No. 2 mine.

Section	A		B	
Laboratory No.	15563		15564	
Roof, clay ("soapstone").	*Ft.*	*in.*	*Ft.*	*in.*
Bone	..	..	[a]0	3
Coal	2	3	2	3
"Sulphur" band	[a]0	¼	[a]0	¼
Coal	[a]0	3½	[a]0	3
"Sulphur" band	[a]0	¼	[a]0	¼
Coal	1	3	2	5
"Sulphur" band	0	⅛	..	..
Coal	0	11	..	..
Floor, clay and shale.				
Thickness of bed	4	9⅛	5	3½
Thickness of coal sampled	4	5⅛	4	8

[a] Not included in sample.

Section A (sample 15563) was measured in face entry 2, north side of mine, 500 feet northwest of the mine mouth. Cover, about 100 feet.

Section B (sample 15564) was measured in room 1, right entry 1, south side, 500 feet northwest of the mine mouth and about 1,200 feet from point where sample 15563 was taken.

Notes.—The output (run-of-mine) was reported at the time of sampling to be 700 tons a day.

HOPEDALE. PARLETT MINE.

Sample.—Bituminous coal; Ohio field; analyses Nos. 15444 and 15445 (p. 62).

Mine.—Parlett, a slope mine in SE. ¼ sec. 32, T. 9 N., R. 3. W, 2 miles southeast of Hopedale, on the Wabash-Pittsburg Terminal Railway.

Coal bed.—Pittsburgh or No. 8 of Ohio Geological Survey. Carboniferous age, Monongahela formation. Average thickness, 4 feet 9 inches. The bed lies nearly flat. The roof is clay and the upper bench of coal characteristic of the Pittsburgh seam. The cover at most places is less than 100 feet.

The bed was measured and sampled at two points in the mine by D. D. Condit on December 31, 1912, as described below:

Sections of coal bed in Parlett mine.

Section	A		B	
Laboratory No.	15444		15445	
Roof, clay or coal.	*Ft.*	*in.*	*Ft.*	*in.*
Coal, impure	..	..	[a]0	11
Clay	..	..	[a]0	3
Coal	..	..	[a]1	1
Clay	[a]1	2	[a]1	0
Coal	2	5½	2	2
Coal with several shale bands	[a]0	3½	[a]0	3
Coal	2	½	2	3
Floor, clay.				
Thickness of bed	5	11½	7	11
Thickness of coal sampled	4	6	4	5

[a] Not included in sample.

Section A (sample 15444) was measured in room 9, off west entry 2, off south entry, 2,200 feet north of the bottom of the slope. Cover, about 30 feet.

Section B (sample 15445) was measured in north entry 2; 180 feet beyond rooms 9 and 10, off west entry, 400 feet northwest of the bottom of the slope. Cover, 28 feet.

Notes.—The mine is very wet. At the time of sampling the output was reported to be 150 tons a day.

PINEY FORK. PINEY FORK NO. 1 AND NO. 2 MINES, AND CABBAGE RUN MINE.

Sample.—Bituminous coal; Ohio field; analyses Nos. 15489, 15490, and 15491 (p. 62).

Mines.—Piney Fork No. 1 and No. 2 mines and Cabbage Run mine, secs. 21, 17, and 16, T. 8 N., R. 3 W., 2 miles southwest of Smithfield, on Lake Erie, Alliance & Wheeling Railroad.

Coal bed.—Pittsburgh or No. 8 of Ohio Geological Survey. Carboniferous age, Monongahela formation. Thickness fairly uniform, about 4½ feet. The bed lies nearly flat. The roof of the main bed of coal is a clay band about 1 foot thick which is taken down in most places. Above this is the "roof" coal, an impure bony bed of variable thickness which has not been mined in this district.

The bed was measured and sampled at one point in No. 1 mine, at one point in No. 2 mine, and at one point in Cabbage Run mine by D. D. Condit on January 3, 1913, as described below:

Sections of coal bed in Piney Fork mines.

Section	A		B		C	
Laboratory No	15489		15490		15491	
Roof, coal or clay.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Bone	[a]0	2	..	..	..	..
Coal	2	7	2	2¼	2	3¼
Clay	[a]0	⅛	[a]0	¼	[a]0	⅛
Coal	[a]0	3	[a]0	3½	[a]0	3½
Clay	[a]0	⅛	[a]0	¼	[a]0	¼
Coal	1	1	1	8	1	3
Clay band	0	⅛	..	..	0	⅛
Coal	0	5	..	..	0	6¾
Coal, high in sulphur	[a]0	3	[a]0	3	[a]0	3
Floor, clay and shale.						
Thickness of bed	4	9⅜	4	5¼	4	8
Thickness of coal sampled	4	1⅛	3	10¼	4	1⅛

[a] Not included in sample.

Section A (sample 15489) was measured in mine No. 1, room 14, off left entry 11 off the main east entry, 4,000 feet southwest of the mine mouth. Cover, 125 feet.

Section B (sample 15490) was measured in mine No. 2, room 28, off east entry 21, 5,600 feet northeast of the mine mouth. Cover, 100 feet.

Section C (sample 15491) was measured in Cabbage Run mine, room 26 off left entry 3, 1,050 feet northeast of the mine mouth. Cover, 50 feet.

Notes.—At the time of sampling there were three drift mines in operation at Piney Fork, No. 1 and No. 2, and Cabbage Run mine. The daily output of screened coal from the three was reported to be about 1,250 tons. Sulphur bands and lenses were rather plentiful, but these were carefully sorted out of the coal.

SMITHFIELD. PLUM RUN NO. 1, NO. 4, AND NO. 5 MINES.

Sample.—Bituminous coal; Ohio field; analyses Nos. 15486, 15487, and 15488 (p. 63).

Mines.—Plum Run mines Nos. 1, 4, and 5, in SW. ¼ and NW. ¼ sec. 29 and sec. 30, T. 5 N., R. 2 W., 2 miles east of Smithfield, on branch of Lake Erie, Alliance & Wheeling Railroad.

Coal bed.—Pittsburgh or No. 8 of Ohio Geological Survey. Carboniferous age, Monongahela formation. Thickness, 4½ to 5 feet. The bed lies nearly flat. The coal is overlain by a layer of clay 1 foot thick; above this clay is the "roof coal," which varies in thickness and was not mined. In the middle of the bed is a "bearing in" layer, 3 to 4 inches thick, which was rejected in mining. The coal above this layer varies considerably in thickness from place to place. "Sulphur" in the form of small scattered lenses and bands was common.

The bed was measured and sampled at one point in No. 1, at one point in No. 4, and at one point in No. 5 mine by D. D. Condit on January 2, 1913, as described below:

Sections of coal bed in Plum Run mines.

Section	A		B		C	
Laboratory No	15486		15487		15488	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, clay.						
Coal	2	3	1	10	2	1
"Sulphur" and clay	[a]0	¼	[a]0	½	[a]0	¼
Coal	[a]0	2½	[a]0	2¾	[a]0	2½
"Sulphur" and clay	[a]0	¼	[a]0	¼	[a]0	¼
Coal	2	3	2	3	2	2½
Floor, clay and shale.						
Thickness of bed	4	9	4	4½	4	6½
Thickness of coal sampled	4	6	4	1	4	3½

[a] Not included in sample.

Section A (sample 15486) was measured in mine No. 1, room 7, off first south face entry, off seventh east entry, 2,500 feet northeast of the mine mouth. Cover, about 50 feet.

Section B (sample 15487) was measured in mine No. 4, room 14, off fifteenth right entry, 4,400 feet northeast of the mine mouth. Cover, 225 feet.

Section C (sample 15488) was measured in mine No. 5, room 3, off second right entry, off first right face entry, 1,800 feet southeast of the mine mouth. Cover, 200 feet.

Notes.—At the time of sampling there were four drift mines in operation here. The combined output of screened coal was reported at 1,350 tons a day.

STEUBENVILLE. LA BELLE MINE.

Sample.—Bituminous coal; Ohio field; analyses Nos. 15675 and 15676 (p. 63).

Mine.—La Belle, a shaft mine in SW ¼, sec. 29, T. 2 N., R. 1 W., on the banks of Ohio River in the city of Steubenville.

Coal bed.—Lower Freeport. Carboniferous age, Allegheny formation. The thickness varies greatly from place to place. The bed lies about 100 feet below river level.

The bed was measured and sampled at two points in the mine by D. D. Condit on January 9, 1913, as described below:

Sections of coal bed in La Belle mine.

Section	A		B	
Laboratory No	15675		15676	
	Ft.	*in.*	*Ft.*	*in.*
Roof, shale.				
Coal	1	9	1	9
Bone	0	½	0	1
Coal	0	9	0	8¼
Shale	[a]0	1¼	[a]0	3
Coal	0	6¼	0	7
Floor, clay, shale.				
Thickness of bed	3	2	3	4¼
Thickness of coal sampled	3	¾	3	1¼

[a] Not included in sample.

Section A (sample 15675) was measured in room 9, off left entry, off second south butt entry, 5,200 feet southeast of the shaft.

Section B (sample 15676) was measured in fifth south butt entry, off southeast entry, 4,400 feet southeast of the shaft.

Notes.—At the time of sampling nearly all the output was from West Virginia territory. The coal was used in iron and steel mills. The coal at the bottom of the bed is somewhat high in sulphur and for that reason was kept separate from the remainder of the bed and used only for steam purposes.

NOBLE COUNTY.

BELLE VALLEY. NOBLE MINE.

Sample.—Bituminous coal; Ohio field; analyses Nos. 17213, 17214, and 17215 (p. 63).

Mine.—Noble, a shaft mine 1 mile northwest of Belle Valley on the Marietta division of the Pennsylvania Railroad.

Coal bed.—Known as No. 7, Carboniferous age, Allegheny formation. Average thickness, about 4 feet 6 inches. Dip, northeast. Rock faults are of frequent occurrence. The roof is shale, roof coal, shale, and sandstone in the order mentioned. The floor is a hard smooth clay. Particles of the roof, but not of the floor, occasionally get mixed with the coal in loading. There are two other workable beds of coal at the Noble mine, one about 250 feet above and the other 100 feet below the No. 7 bed.

The bed was measured and sampled at two points in the mine by H. D. Mason, jr., and G. W. Salisbury on May 21, 1913, as described below.

Sections of coal bed in Noble mine.

Section	A		B	
Laboratory No.	17213		17214	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*
Top coal laminated with mother coal	0	6⅛	0	5
Coal	1	9	0	10¾
Mother coal	..	..	0	1
Coal	..	..	1	3
Bony coal	..	..	0	2¼
"Sulphur"	0	1	..	..
Coal	0	8	1	6
"Slate" binder	[a] 0	3	[a] 0	2
Coal	0	10	0	10
Bottom coal	0	2	..	..
Floor, underclay.				
Thickness of bed	4	3⅛	5	4
Thickness of coal sampled	4	⅛	5	2

[a] Not included in sample.

Section A (sample 17213) was measured at the face of eighth south entry (motor road), 5,700 feet southwest of the shaft bottom.

Section B (sample 17214) was measured at the face of room 5 off seventh south entry, 5,600 feet southwest of the shaft bottom.

A composite sample was made by mixing samples 17213 and 17214. The results of an ultimate analysis of this sample are given under laboratory No. 17215.

Note.—The shaft is 185 feet deep. The mine is worked by the room-and-pillar method. At the time of sampling the coal was shot down with FF black blasting powder. Dynamite was used for brushing the floor and roof. About 80 per cent of the coal was shipped as run-of-mine. About 33 per cent of the coal going to the screens passed through. The screens consisted of bars 72 feet long with 1¼ and ¾ inch openings. Pickers were employed on the cars in loading. There were three loading tracks with a capacity of 50 empty cars and 50 loaded cars. The average daily output was 600 tons, with a capacity of 1,500 tons. There was about 200 acres to be mined from this opening.

OKLAHOMA.

HASKELL COUNTY.

McCURTAIN. SAN BOIS NO. 2 MINE.

Sample.—Bituminous (coking) coal; McAlester field; analyses Nos. 13688, 13689, 13690, 13691, 13692, and 13693 (p. 64).

Mine.—San Bois No. 2, a slope mine, 1 mile west of McCurtain, on the Fort Smith & Western Railway.

Coal bed.—McCurtain (Hartshorne) bed. Carboniferous (Allegheny) age, McAlester shale. Average thickness, 7 feet. Roof, shale of medium quality; floor, hard clay with smooth surface. Dip, 7° S. Cover at points of sampling, about 225 feet.

The bed was measured and sampled at five points in the mine by R. Y. Williams on March 30 and April 2, 1912, as described below:

Sections of coal bed in the San Bois No. 2 mine.

Section	A	B	C	D	E
Laboratory No	13688	13689	13690	13691	13692
Roof, dark gray limey shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal, soft, bright, granular	2 2½	2 4	2 3⅞	2 6¼	2 1
Bone	[a]2 3	[a]1 7⅞	[a]1 4	[a]3 2⅝	[a]1 2
Coal, soft and bright	0 10½	1 7¼	0 11⅞	1 ½	0 6
"Sulphur" and bony coal	[a]0 ⅝	0 ⅛	0 ¼	[a]0 ⅜	0 ¼
Coal, soft and bright	1 ⅜	1 8⅛	2 2	2 2	2 8¾
Coal, containing 3 bone streaks	0 1	.. ..	.. ..	.. ..	.. ..
Coal, soft and bright	1 6⅜	.. ..	.. ..	.. ..	.. ..
Floor, hard shale.					
Thickness of bed	8 ⅜	7 3⅜	6 10	8 11¾	6 6
Thickness of coal sampled	5 8¾	5 7½	5 6	5 8¾	5 4

[a] Not included in sample.

Section A (sample 13688) was measured at the face of thirteenth south entry, 5,000 feet west of the slope mouth.

Section B (sample 13689) was measured at the face of room 3, off thirteenth north entry, top side, 5,000 feet west of the slope mouth.

Section C (sample 13690) was measured at the face of eleventh south entry, 50 feet south of the slope and 5,000 feet west of the slope mouth.

Section D (sample 13691) was measured at the face of twelfth south entry in the top side, 5,500 feet west of the slope mouth.

Section E (sample 13692) was measured at the neck of room 6, twelfth north entry, top side, 5,300 feet west of the slope mouth.

Notes.—The mine is worked on the room-and-pillar system. At the time of sampling the coal was shot off the solid with dynamite. The lower bench was mined first, then the "dirt" band was removed and the upper 3 feet of coal was blasted. The tipple was provided with bar screens and the entire output was screened. The screenings were washed and coked, there being 210 ovens at this plant. Pickers were employed on the cars. The average daily output was about 600 tons.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 149, 675.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 260, 1905, p. 382.

PITTSBURG COUNTY.

ADAMSON. ECLIPSE NO. 1 MINE.

Sample.—Bituminous coal; McAlester field; analyses Nos. 16143, 16144, and 16145 (p. 64).

Mine.—Eclipse No. 1, a slope mine in sec. 9, T. 5 N., R. 17 E., 1½ miles east of Adamson, on the Missouri, Kansas & Texas Railway.

Coal bed.—Lower Hartshorne, Carboniferous (Allegheny) age, McAlester shale. Average thickness, 4 feet 6 inches. Dip, 38° northwest. Cleat, east and west. No faults, rolls, or horsebacks are encountered. The immediate roof is a "draw slate" 1 to 8 inches thick which comes down with the coal; above the "slate" is a gray shale. The floor is a hard smooth shale. Particles from both the floor and roof get mixed with the coal in mining. Cover at points of coupling, about 200 feet. The bed was measured and sampled at two points in the mine by W. T. Burgess on January 30, 1913.

Section A (sample 16143) was measured at the face of the third east entry, 600 feet northeast of the mouth of the slope. The sample represents 4 feet 6 inches of clean coal, the thickness of the bed.

Section B (sample 16144) was measured at the face of the third west entry, 600 feet northwest of the mouth of the slope. The sample represents 4 feet of clean coal, the thickness of the bed.

A composite sample was made by combining samples 16143 and 16144. The ultimate analysis of this sample is given under laboratory No. 16145.

Notes.—The mine is worked by the room-and-pillar system. At the time of sampling the coal was shot off the solid with black powder and "40 per cent" dynamite. These explosives were also used in brushing the floor and roof. The coal was all shipped as run-of-mine. Pickers were employed on the cars. The daily output was about 100 tons, all from advance workings. The mine had a probable life of about five years.

ALDERSON. ALDERSON NO. 5 MINE.

Sample.—Bituminous coal; McAlester field; analyses Nos. 11915, 11916, 11917, and 11918 (p. 65).

Mine.—Alderson No. 5, a shaft mine in sec. 15, T. 5 N., R. 15 E., 1½ miles southwest of Alderson, on the Chicago, Rock Island & Pacific Railway.

Coal bed.—McAlester. Carboniferous (Allegheny) age, McAlester shale. Average thickness, 3 feet 6 inches; dip, 9° southwest. Roof, smooth bluish-gray shale; floor, hard, rough fire clay. Cover, 320 to 625 feet. The bed was measured and sampled at four points in the mine by H. I. Smith on March 6, 1911, as described below:

Sections of coal bed in Alderson No. 5 mine.

Section	A		B		C		D	
Laboratory No	11915		11916		11917		11918	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, shale.								
Coal, bony	..	..	..	..	[a]0	4	..	..
Shale and coal	..	..	..	..	[a]0	6	..	..
Coal, soft	..	..	..	..	0	6	0	7
Coal, uniform	3	7	3	5	2	0	3	0
Floor, clay.								
Thickness of bed	3	7	3	5	3	4	3	7
Thickness of coal sampled	3	7	3	5	2	6	3	7

[a] Not included in sample.

Section A (sample 11915) was measured at the face of room 1, off the fourth west back entry, off the west slope, 2,200 feet west of the shaft.

Section B (sample 11916) was measured at the face of room 7, off seventh west entry, off the west slope, about 2,800 feet northwest of the shaft.

Section C (sample 11917) was measured at the face of room 66, off eleventh east entry, off the east slope, about 4,000 feet east of the shaft.

Section D (sample 11918) was measured at the face of second west entry, off the east slope, about 2,000 feet southeast of the shaft. This section contained a "sulphur" band one-eighth inch thick about 7 inches from the top.

Notes.—The mine is worked by the room-and-pillar system; the shaft is 555 feet deep. At the time of sampling the coal was undercut and was shot down with FF black powder and a permissible explosive. The coal was friable, about 75 per cent passing through a 4-inch screen. Pickers were employed on the cars in loading. The four loading tracks had a capacity of 25 empty cars and 100 loaded cars. The daily output was 400 tons, all from advance workings. The pillars were not robbed.

ALDERSON. ALDERSON NO. 38 MINE.

Sample.—Bituminous coal; McAlester field; analyses Nos. 11592, 11594, 11670, 15188, and 15189 (p. 65).

Mine.—Alderson No. 38, a slope mine in T. 5 N., R. 15 E., 2 miles east of Alderson, on the Chicago, Rock Island & Pacific Railway.

Coal bed.—McAlester. Carboniferous (Allegheny) age, McAlester shale. Average thickness, 3 feet 5 inches; dip, 15° to 17° south. Roof, bluish-gray shale; floor, hard, brittle clay. Cover at points of sampling, 425 to 750 feet.

The bed was measured and sampled at three points in the mine by H. I. Smith on January 17 and 30, 1911, and at two points by C. S. Stevenson and W. T. Burgess on December 1, 1912.

Sample 11592 was taken in room 1, off seventh west entry, about 2,200 feet down the main slope. The sample represents 2 feet 9 inches of clear coal.

Sample 11594 was taken in room 4, off fifth east entry, about 2,300 feet down the main slope. The sample represents 3 feet 3 inches of clear coal.

Sample 11670 was taken in room 26, off fourth east entry, about 1,900 feet down the main slope. The sample represents 3 feet 2 inches of coal that contained a few thin seams (less than one-eighth inch thick) of bony coal.

Sample 15188 was taken at the face of sixth east entry, and represents 3 feet 6 inches of coal.

Sample 15189 was taken at the face of seventh west air course, and represents 3 feet 9 inches of coal.

Each sample represents the thickness of the bed at that point.

Notes.—The mine is worked by the room-and-pillar system. At the time of sampling the coal was shot from the solid with FF black powder. None of the coal was shipped as run-of-mine during 1910. About 33 per cent of the coal would pass through a 2½-inch screen. The coal was not washed. There were 5 loading tracks with a capacity of 14 empty and 14 loaded cars. The capacity was 200 tons a day.

CRAIG. BOLEN-DARNALL NO. 4 MINE.

Sample.—Bituminous coal; McAlester field; analyses Nos. 15104 and 15105 (p. 65).

Mine.—Bolen-Darnall No. 4, a slope mine in Craig, on the Ardmore branch of the Chicago, Rock Island & Pacific Railway.

Coal bed.—Lower Hartshorne (?). Carboniferous (Allegheny) age, McAlester shale. Thickness, fairly uniform, average about 3 feet. Roof, bluish sandy shale, soft in places. Floor, hard rough clay, which becomes soft when exposed to the action of water. Cover at points of sampling, about 700 feet.

The bed was measured and sampled at two points in the mine by W. T. Burgess and C. S. Stevenson on November 12, 1912, as described below:

Sections of coal bed in Bolen-Darnall No. 4 mine.

Section	A		B	
Laboratory No.	15104		15105	
Roof, gray shale.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	5¾	3	½
"Sulphur" band	[a] 0	1	..	..
Coal	1	4⅞	..	..
Floor, fire clay.				
Thickness of bed	2	11⅝	3	½
Thickness of coal sampled	2	10⅝	3	½

[a] Not included in sample.

Section A (sample 15104) was measured at the face of eighth west entry, 3,000 feet northwest of the mouth of the slope.

Section B (sample 15105) was measured at the face of eighth east entry, 3,000 feet from the mouth of the slope.

Notes.—The mine is opened by a slope and is worked on the room-and-pillar system. The coal from this mine, like many others in this field, breaks easily into small pieces. In 1910 about 55 per cent of the coal passed through the screens. Only a small proportion was shipped as run-of-mine. The average daily output was about 150 tons.

McALESTER. BUSBY NO. 5 MINE.

Samples.—Bituminous coal; McAlester field; analyses Nos. 11569, 11586, 11587, 11588, 11589, 11590, and 11591 (p. 65).

Mine.—Busby No. 5, a shaft mine in sec. 32, T. 6 N., R. 15 E., 2 miles east of McAlester on the Chicago, Rock Island & Pacific Railway and the Missouri, Kansas & Texas Railway.

Coal bed.—McAlester. Carboniferous (Allegheny) age, McAlester shale. Average thickness, 4 feet; dip, 10° S. 15° W.; cleat, S. 30° E. Roof, bluish-gray shale 30 feet thick; floor, hard fire clay. Cover at points of sampling, 550 to 720 feet.

The bed was measured and sampled at six places in the mine by H. I. Smith on January 11 and 19, 1911.

Sample 11569 was taken in room 11, off third west entry, off the east slope, about 1,600 feet from the shaft. The sample represents 4 feet 2 inches of clear coal, the thickness of the bed.

Sample 11586 was taken at the face of second west entry, off the west slope, 300 feet beyond room 26. The sample represents 4 feet of coal that contained a ⅛-inch band of "sulphur" about 4 inches from the top.

Sample 11587 was taken at the face of third east entry, off the east slope, 120 feet beyond room 22. The sample represents the thickness of the bed, 4 feet 2 inches; the upper three-fourths of an inch was bony coal.

Sample 11588 was taken at the face of fourth east entry, off the west slope. The bed was 4 feet thick and contained ⅛-inch band of "sulphur," 8½ inches from the top. The top inch was bony coal. The sample represents the entire thickness of the bed.

Sample 11589 was taken at the face of fifth east entry, off the east slope, where the bed was 4 feet 3 inches thick. The sample represents 4 feet 1½ inches of coal. There was 1½ inches of bony coal above the part sampled.

Sample 11590 was taken at the face of third east entry, off the west slope, 200 feet beyond room 8. The sample represents the entire thickness of the bed. The bed was 4 feet thick, the top inch was bony coal, and there was a band of "sulphur" ⅛ inch thick, 10 inches from the top.

A composite sample was made by mixing face samples 11586 to 11590. The results of an ultimate analysis of this sample are given under Laboratory No. 11591.

Notes.—The mine is worked by the room-and-pillar system. At the time of sampling the coal was shot from the solid with FF black powder. Only a small proportion of the coal was sold as run-of-mine. About 65 per cent of the coal going to the screens would pass through a 2-inch screen. Pickers were employed on the cars and at the shaking screens. There was no washery. The four loading tracks had a capacity of 20 empty and 20 loaded cars. The output was 600 tons a day; the unmined area tributary to this opening, 200 acres.

OREGON.

COOS COUNTY.

WEST FORK. FLANIGAN PROSPECT.

Sample.—Bituminous coal; Eden Ridge field; analysis No. 14828 (p. 66).

Mine.—Flanigan prospect, in NE. ¼ sec. 28, T. 32 S., R. 11 W., 36 miles southwest of West Fork (Dothan post office), on the Southern Pacific Railway.

Coal bed.—Anderson. Tertiary (Eocene) age, Arago formation.

The bed was measured and sampled by M. R. Campbell on September 24, 1912, as described below:

Section of coal bed in Flanigan prospect.

Laboratory No.	14828	
Roof, shale.	*Ft.*	*in.*
Coal	0	3½
Bone	0	2
Coal	1	6
Coal, bony	0	5
Clay, white	[a] 0	2
Coal	0	8
Bone	[a] 0	2½
Coal	0	6
Bone	0	3
Coal, soft, weathered (not mined)	1	4
Floor, clay.		
Thickness of bed	5	6
Thickness of coal sampled	5	1½

[a] Not included in sample.

Notes.—The sample was taken in the entry, 125 feet from the mouth of the entry, and represents wet coal.

WEST FORK. HAMMOND PROSPECT.

Sample.—Bituminous coal; Eden Ridge field; analysis No. 14831 (p. 66).

Mine.—Hammond prospect, in SW. ¼ NE. ¼ sec. 29, T. 32 S., R. 11 W., 37 miles southwest of West Fork (Dothan post office), on the Southern Pacific Railway.

Coal bed.—Carter. Tertiary (Eocene) age, Arago formation.

The bed was measured and sampled at one point in the mine by M. R. Campbell on September 26, 1912, as described below:

Section of coal bed in Hammond prospect.

Laboratory No.	14831	
	Ft.	*in.*
Roof, shale and coal.		
Coal	0	10½
Bone and coal	[a]0	8
Coal	0	7
Bone and coal	[a]0	11
Coal	1	1
Bone	[a]0	2
Coal	1	8½
Floor, clay.		
Thickness of bed	6	0
Thickness of coal sampled	4	3

[a] Not included in sample.

Notes.—The sample was collected in the entry, 100 feet from the drift mouth, and represents dry coal.

WEST FORK. HILLIS PROSPECT.

Sample.—Bituminous coal; Eden Ridge field; analysis No. 14827 and 14830 (p. 66).

Mine.—Hillis prospect, in SE. ¼ NE. ¼ sec. 32, T. 32 S., R. 11 W., 36 miles southwest of West Fork (Dothan post office), on the Southern Pacific Railway.

Coal bed.—Anderson. Tertiary (Eocene) age, Arago formation.

The bed was measured and sampled at two points in the prospect by M. R. Campbell on September 24, 1912, as described below:

Sections of coal bed in Hillis prospect.

Laboratory No.	14827		14830	
	Ft.	*in.*	*Ft.*	*in.*
Roof, shale.				
Coal	[a]0	1½	0	1½
Bone	[a]0	½	0	½
Coal	[a]0	4½	0	4½
Bone	[a]0	½	0	½
Coal	[a]2	2½	2	2½
Clay, white	[a]0	3	[a]0	3
Coal	[a]0	2	[a]0	2
Bone and bony coal	[a]1	5	[a]1	5
Coal	1	3½	[a]1	3½
Coal, soft	[a]0	3	[a]0	3
Bone	[a]0	8	[a]0	8
Floor, clay.				
Thickness of bed	6	10	6	10
Thickness of coal sampled	1	3½	2	9½

[a] Not included in sample.

Notes.—Both samples were taken in the entry, 90 feet from the mouth. Sample 14827 represents wet coal and sample 14830 represents dry coal.

WEST FORK. VANDERPOOL PROSPECT.

Sample.—Bituminous coal; Eden Ridge field; analysis No. 14829 (p. 67).

Mine.—Vanderpool prospect, in NW. ¼ NE. ¼ sec. 30, T. 32 S., R. 11 W., 38 miles southwest of West Fork (Dothan post office), on the Southern Pacific Railway.

Coal bed.—Anderson. Tertiary (Eocene) age, Arago formation.

The bed was measured and sampled at one point in the mine by M. R. Campbell on September 27, 1912, as described below:

Section of coal bed in Vanderpool prospect.

Laboratory No	14829	
Roof, shale.	*Ft.*	*in.*
Coal	[a]0	3
Bone	[a]0	7
Coal	0	2
Bone	0	1
Coal, good	1	7
Bone	[a]0	3
Clay, white	[a]0	5
Coal, hard	[a]0	9
Coal, soft, laminated	[a]1	9½
Floor, clay.		
Thickness of bed	5	10½
Thickness of coal sampled	1	10

[a] Not included in sample.

Notes.—The sample was taken in the entry, 217 feet from the mouth of the entry, and represents dry coal.

MALHEUR COUNTY.

NYSSA. HONOLULU PROSPECT.

Sample.—Lignite; analysis No. 12585 (p. 67).

Mine.—Honolulu prospect, in NE. ¼ sec. 2, T. 22 S., R. 44 E. (unsurveyed), about 25 miles southwest of Nyssa, on the Oregon Short Line Railroad.

Lignite bed.—Not named. Tertiary (Miocene?) age, Payette formation. Thickness, 2 feet 4 inches; variable. Dip, about 6° SW.; strike, N. 37° W. The bed is irregular in character. Roof, shale; floor, clay. At an opening about 1,000 feet north of the point of sampling the bed is cut by a sill of basalt and in places is metamorphosed to high-grade coal, which occurs in small lenses.

The bed was measured and sampled at one point in the mine by C. F. Bowen on July 24, 1911, as shown below:

Section of lignite bed at Honolulu prospect.

Laboratory No	12585	
Roof, shale.	*Ft.*	*in.*
Lignite, fair	0	8
Lignite, bony	[a]1	8
Floor, clay, sandy.		
Thickness of bed	2	4
Thickness of lignite sampled	0	8

[a] Not included in sample.

The sample was taken at the mouth of the slope; the lignite was more or less weathered.

PENNSYLVANIA.

ALLEGHENY COUNTY.

BRUCETON. EXPERIMENTAL MINE.

Sample.—Bituminous coal; Pittsburgh field; analyses Nos. 11983, 11984, 11985, 11986, 12251, 12262, 12264, 12274, 12557, 12569, 12572, 12577, 14797, and 14798 (p. 67).

Mine.—The Experimental mine of the United States Bureau of Mines is a drift opening in the Pittsburgh district, about 1 mile south of Bruceton, near the Baltimore & Ohio Railroad siding at Wallace Station.

Coal bed.—Pittsburgh. Carboniferous age, Monongahela formation. Average thickness at mine, about 5 feet 3 inches. The roof is a "draw slate" 10 to 12 inches thick, above which there are thin strata of coal and shale, overlain by shale. The coal above the "draw slate" adheres to the roof shale. The floor is a fire clay. The bed is practically horizontal and the cover at the points where the samples were taken is 15 to 140 feet thick.

The bed was measured and sampled at three points in the mine by L. M. Jones on April 4, 1911, and at nine points by H. I. Smith between May, 1911, and October, 1912, as described below:

Sections of coal bed at Experimental mine.

[SECTIONS A TO F.]

Section	A	B	C	D	E	F
Laboratory No.	11983	11984	11985	12251	12262	12264
Roof, "draw slate."	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	1 8	3 1½	2 3	3 3	2 8	2 7
Shale	.. ..	[a]0 ¼	.. ..	.. ..	.. ..	....
Soft dirt and "sulphur"	0 ¼	.. ..	.. ..	.. ..	.. ..	[a]0 ½
Coal	0 ½	0 2¾	.. ..	.. ..	.. ..	.. ..
Fire clay	.. ..	.. ..	.. ..	[a]0 ½	.. ..	.. ..
Soft dirt and "sulphur"	0 ¼	.. ..	0 ½	.. ..	Streak.	.. ..
Coal	1 5¼	.. ..	0 6¼	0 3	0 6½	0 3
Shale	0 ⅛	[a]0 1	[a]0 ½	[a]0 ½	[a]0 ¾	[a]0 ½
Coal	0 3½	1 1½	0 2½	0 5⅝	0 3	0 3
Shale	[a]0 ⅝	.. ..	[a]0 1¼	.. ..	[a]0 ¾	[a]0 ¾
Coal	.. ..	.. ..	0 3½	.. ..	.. ..	0 3
"Sulphur" band	.. ..	[a]0 1/16	[a]0 ½	.. ..	.. ..	[a]0 ¾
Coal	2 2	0 9¼	1 9	1 11	2 5	1 10½
Dirty coal and shale	[a]0 2½	[a]0 3	.. ..	.. ..	.. ..	.. ..
Floor, fire clay.						
Thickness of bed	5 11	5 7 1/16	5 3	5 11⅝	6 0	5 5
Thickness of coal sampled	5 7⅞	5 3	5 ¾	5 10⅝	5 10½	5 2½

[a] Not included in sample.

[SECTIONS G TO L.]

Section	G	H	I	J	K	L
Laboratory No.	12557	12569	12572	12577	14797	14798
Roof, "draw slate."	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	1 5	1 4½	1 10½	1 3	0 8½	0 4½
"Sulphur" or bone	0 ½	0 ½	0 ½	0 ½	[a]0 1¼	0 ¼
Coal	1 5½	1 6	0 1	0 2½	0 7½	0 5½
"Sulphur" and shale	.. ..	.. ..	0 ½	Streak.	[a]0 ½	[a]0 ½
Coal	.. ..	.. ..	0 10½	0 7½	0 11	1 5
"Sulphur"	.. ..	.. ..	.. ..	Streak.	0 ¼	Streak.
Coal	.. ..	.. ..	.. ..	0 8	0 10	0 8
Shale binder	0 ½	[a]0 ½	Streak.	0 ½	[a]0 ¾	Streak.
Coal	0 3	0 2½	0 2½	0 3	.. ..	0 3¼
Shale binder	.. ..	[a]0 ¾	[a]0 1	.. ..	.. ..	[a]0 1
Bone	0 1	.. ..	.. ..	0 1	.. ..	.. ..
Coal	0 3	.. ..	0 1	0 1	0 10¼	0 3
"Sulphur" balls	0 1	.. ..	0 1½	0 1	.. ..	0 1¼
Coal	1 4½	0 11	0 7½	0 10	.. ..	.. ..
Mother coal	0 ½	0 ½	.. ..	0 ¼	0 ¼	.. ..
Coal	0 1	.. ..	.. ..	0 2½	1 3¼	1 8
Bony coal	0 ½	.. ..	0 ½	Streak.	.. ..	.. ..
Coal	0 2	0 8½	0 10	0 8	.. ..	.. ..
Dirty coal	.. ..	[a]0 4	[a]0 3	[a]0 2	.. ..	[a]0 3
Floor, underclay.						
Thickness of bed	5 4	5 2¾	5 2	5 2¾	5 5½	5 7¼
Thickness of coal sampled	5 4	4 9½	4 10	5 ¾	5 3	5 2¾

[a] Not included in sample.

Section A (sample 11983) was measured on the rib of the first crosscut, about 200 feet from the mouth of the air course.

Section B (sample 11984) was measured on the rib near the face of the air course, 390 feet from the mouth of the air course.

Section C (sample 11985) was measured at the face of the main entry, 345 feet from the mouth of the main entry.

A composite sample was made by mixing samples 11983, 11984, and 11985. The results of an analysis of this sample are shown under laboratory No. 11986.

Section D (sample 12251) was measured in the air course, about 75 feet from the outcrop at the mouth of the air course.

Section E (sample 12262) was measured on the left side of the air course, about 150 feet from the mouth of the air course.

Section F (sample 12264) was measured on the left side of the air course, about 430 feet from the outcrop at the mouth of the air course.

Section G (sample 12557) was measured on the right side of the main entry, 680 feet in by the outcrop.

Section H (sample 12569) was measured on the right side of the main entry, 530 feet in by the outcrop.

Section I (sample 12572) was measured on the right side of the main entry, 580 feet in by the outcrop.

Section J (sample 12577) was measured on the right side of the main entry, 630 feet in by the outcrop.

Section K (sample 14797) was measured in the crosscut off the main entry, at station E-1250, 3 feet from the main entry.

Section L (sample 14798) was measured in the main entry at station E-1270.

Notes.—The Experimental mine is opened by parallel air course and entry, which at the time the last samples were taken, were in about 1,270 feet. The mine is used for experiments made in connection with investigations of the Bureau of Mines. No attempt is made to produce coal to supply a regular demand. All the coal is shipped as run-of-mine.

CREIGHTON. HITE MINE.

Sample.—Bituminous coal; Beaver field; analyses Nos. 11130, 11132, and 11133 (p. 68).

Mine.—Hite; a drift mine in the Pittsburgh district, at Creighton, on the Western Pennsylvania branch of the Pennsylvania Railroad. The mine opening is about one-eighth of a mile from the Allegheny River but none of the coal is shipped by water.

Coal beds.—Upper Freeport or E and Lower Freeport or D, of the State Geological Survey. Carboniferous age, Allegheny formation. At this mine the beds are separated by less than 1 foot of bony coal. Average thickness about 5 feet 10 inches. The coal outcrops on a hillside and lies practically level; slight variations of dip are due to local rolls. The face cleavage strikes approximately northeast and the butt cleavage about southwest. The coal is of good quality. The immediate roof, a hard gray shale, is overlain by about 1 foot 6 inches of cannel coal. The floor is a smooth hard fire clay. The bed was measured and sampled at two points in the mine by L. M. Jones and J. J. Rutledge on October 28, 1910, as described below:

Sections of coal bed in Hite mine.

Section	A		B	
Laboratory No.	11130		11132	
Roof, cannel coal.	*Ft.*	*in.*	*Ft.*	*in.*
Coal, clean and hard	..	..	0	4
Mother coal	..	..	0	½
Coal	2	4	2	2
Coal, bony	[a] 0	11	[a] 0	8
Coal	2	7	2	8½
Floor, fire clay.				
Thickness of bed	5	10	5	11
Thickness of coal sampled	4	11	5	3

[a] Not included in sample.

Section A (sample 11130) was taken at the face of room 17, off first butt entry, about 8,000 feet west of the mine mouth.

Section B (sample 11132) was taken at the face of room 18, off third butt entry 9,000 feet from the mine mouth.

A grab sample of the cannel coal, 1 foot 3 inches thick, from above the coal mined was taken at the intersection of the line entry and main entry 1, for approximate analysis of which see Laboratory No. 11133.

Notes.—The coal is mined by the room-and-pillar system. At the time of sampling the tipple had screens, and there was trackage for 25 or 30 cars. The daily output was about 350 tons. The mine is old, having been in operation about 30 or 40 years.

OAK STATION. OAK MINE.

Sample.—Bituminous coal; Pittsburgh field; analysis No. 10845 (p. 68).

Mine.—Oak, a drift mine at Oak Station in the Pittsburgh district, on the Castle Shannon (narrow gage) railroad, a short distance south of Pittsburgh.

Coal bed.—Pittsburgh. Carboniferous age, Allegheny formation. Average thickness, 5 feet 4 inches. The roof, a "draw slate" about 12 inches thick, is overlain with 12 inches of bony coal with a sandstone cap rock. The floor at the point of sampling is limestone. The coal lies practically level. Cover at point of sampling, 85 feet. The bed was measured and sampled at one point in the mine by L. M. Jones on September 9, 1910, as described below:

Section of coal bed in the Oak mine.

Laboratory No.	10845	
Roof, "draw slate."	*Ft.*	*in.*
Coal	0	7
"Sulphur" band	[a] 0	½
Coal	2	11
"Sulphur" band	[a] 0	½
Coal	0	1½
"Sulphur" band	[a] 0	½
Coal	1	7½
Floor, limestone.		
Thickness of bed	5	4½
Thickness of coal sampled	5	3

[a] Not included in sample.

This section (sample 10845) was measured in room 10, off left entry 13, 5,300 feet north of the mine mouth.

Notes.—The coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut with punching machines and shot down with FF black powder. The mine was equipped for producing 400 tons a day; about 60 per cent of the output was from advance workings, the remainder from pillars. When the pillars were robbed the recovery amounted to about 90 per cent of the coal. All of the coal was screened over 1¼-inch bar screens; the screenings amounted to about 30 per cent of the output.

BEDFORD COUNTY.

HOPEWELL. CAMBRIA NO. 3 MINE.

Sample.—Semibituminous coal; Broadtop field; analyses Nos. 15055, 15056, 15057, 15058, 15059, and 15060 (pp. 68, 69).

Mine.—Cambria No. 3, a shaft mine 2 miles east of Hopewell, on the Huntingdon & Broadtop Railroad.

Coal bed.—Upper Freeport, locally known as the Kelley. Carboniferous age, Allegheny formation. Thickness, 3 to 5 feet, average 4 feet. There is about 6 inches of "draw slate" above the coal. Roof, smooth shale; floor, smooth brittle underclay, particles of which sometimes were mixed with the coal in loading. Cover at points of sampling, 225 feet.

The bed was measured and sampled at five points in the mine by H. I. Smith on November 8 and 9, 1912, as described below.

Sections of coal bed in Cambria No. 3 mine.

Section	A		B		C		D		E	
Laboratory No.	15055		15056		15057		15058		15059	
Roof, shale and "draw slate."	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	4½	[a] 0	4½	1	4	1	4	1	4½
Shale	0	¼	[a] 0	½	..	..	..	..	..	..
Coal	0	6	1	7	..	..	..	..	..	..
Mother coal and "sulphur"	0	¼	..	..	..	..	..	..	..	..
Coal	0	2½	..	..	..	..	..	..	..	..
Coal, hard, gray	0	3½	0	2	0	4	0	3½	..	..
Coal, broken	..	..	..	..	..	..	..	..	0	6½
Coal	0	4	0	8	0	5	0	3½	..	..
Coal and broken shale mixed	0	2½	..	..	0	3½	0	5	..	..
Coal, bony	..	..	0	3	..	..	..	..	..	..
Coal, soft, brittle	..	..	0	2¼	..	..	..	..	..	..
Coal	0	8½	..	..	0	8½	1	2	0	8½
"Sulphur"	0	⅛	..	..	Streak.		..	..	Streak.	
Coal, bony	..	..	..	..	..	..	0	½	..	..
Coal	0	9½	1	5	0	4	0	5	1	0
Shale	[a] 0	1	..	..	0	2	..	..	..	..
Coal	0	4	..	..	0	4½	0	0	0	0
Floor, clay.										
Thickness of bed	3	10⅝	4	8¼	3	11½	3	11½	3	7½
Thickness of coal sampled	3	9⅝	4	3¼	3	11½	3	11½	3	7½

[a] Not included in sample.

Section A (sample 15055) was measured at the face of room 7 off second heading, 7,000 feet northeast of the shaft.

Section B (sample 15056) was measured near the face, 600 feet to the right from top of third plane, 5,100 feet northeast of the shaft.

Section C (sample 15057) was measured at the face of second heading, 7,300 feet northeast of the shaft.

Section D (sample 15058) was measured at the face of third heading, 7,400 feet northeast of the shaft.

Section E (sample 15059) was measured at a point 200 feet from face of fourth heading, 7,000 feet northeast from shaft.

A composite sample was made by combining face samples 15055, 15056, 15058, and 15059. The results of an ultimate analysis of this sample is given under laboratory No. 15060.

Notes.—The room-and-pillar system of mining is employed. At the time of sampling the coal was undercut by hand and shot down by FFF black powder. All coal was shipped as run-of-mine. Pickers were employed on the cars in loading. There were two tracks with a capacity of 32 empty cars and 32 loaded cars.

CAMBRIA COUNTY.

BARNESBORO. ALLPORT MINE.

Sample.—Bituminous coal; Windber field; analyses Nos. 12221, W19738, W19739, W19740, W19741, W19742, and W19743 (p. 69).

Mine.—Allport, a drift mine in the Clearfield district, 1 mile east of Barnesboro, on the Pennsylvania Railroad.

Coal beds.—Lower Freeport or D and Upper Freeport or E. Carboniferous age, Allegheny formation. Average thickness of D bed, 4 feet 5 inches; of E bed, 3 feet 7 inches. Each bed has a roof of smooth shale and a floor of smooth hard fire clay.

The D bed was measured and sampled at three points in the mine and the E bed at three points by P. M. Riefkin on April 26, 1911, as described below:

Sections of D bed in Allport mine.

Section	A		B		C	
Laboratory No	W19740		W19741		W19742	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, shale.						
Cannel coal	[a]0	1¾	0	1½	0	2¾
Coal	0	10¼	1	4	0	10
Mother coal	0	⅛	0	½	..	..
Coal	0	10¼	0	9	..	..
"Sulphur" and mother coal	0	⅛	0	1	Streak.	
Coal	0	6¼	0	4¼	1	4¼
Hard coal	0	1	0	½	0	1
Coal	0	9¼	1	1¼	1	1
Shale	[a]0	1	[a]0	½	[a]0	1¼
Coal	1	½	0	11¾	0	11¾
Floor, hard fire clay ("bastard slate").						
Thickness of bed	4	4½	4	10¼	4	8
Thickness of coal sampled	4	1¾	4	9¾	4	6¾

[a] Not included in sample.

Section A (sample W19740) was measured at the face of left entry2, off heading 9, off the main heading, 6,250 feet southeast of the mine mouth.

Section B (sample W19741) was measured on the rib in room 7, left entry 2, off right entry 9, off the main heading, 6,250 feet southeast of the mine mouth.

Section C (sample W19742) was measured at the face of right entry 9, off the main heading, 6,950 feet southwest of the mine mouth.

Sections of E bed in Allport mine.

Section	A		B		C	
Laboratory No	W19738		W19739		W19743	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, shale.						
Coal, bony	[a]0	½	..	..	..	..
Coal	0	11	1	1	1	2
"Sulphur" and mother coal	[a]0	½	0	½	0	½
Coal	1	3½	0	6	1	3¼
Mother coal	Streak.		Streak.		..	..
Coal, hard	0	5	1	1	0	3
Coal, bony	[a]0	1¼	[a]0	1	0	½
Coal	0	10½	0	9½	0	10½
Floor, hard fire clay ("bastard slate").						
Thickness of bed	3	8¼	3	7	3	7¾
Thickness of coal sampled	3	6	3	6	3	7¾

[a] Not included in sample.

Section A (sample W19738) was measured at the face of third right entry, off the main heading, 3,700 feet southeast of the mine mouth.

Section B (sample W19739) was measured at the face of the main slant off the main entry, 3,700 feet southeast of the mine mouth.

Section C (sample W19743) was measured 600 feet in on the second panel from the main slant off the main entry, 2,800 feet south of the mine mouth.

A composite sample was made by combining face samples W19740, W19741, and W19742. The results of an ultimate analysis of this sample are shown under laboratory No. 12221.

Notes.—At the time of sampling the coal was undercut with compressed air punchers and broken down with FFFF black powder. All the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track at the tipple with a capacity of 18 empty and 19 loaded cars. The mine had a capacity of 900 tons a day with an average daily output of 700 tons, 60 per cent of which was from advance workings. It was expected that the output would be increased to 900 tons a day. There was approximately 235 acres of unmined coal in the D bed and 370 acres in the E bed. The coal from both beds was loaded over the same tipple.

BARNESBORO. CYMBRIA MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. W20394, W20395, W20444, W20445, W20446, and 12372, (p. 69).

Mine.—Cymbria, a shaft mine in the Clearfield district, 1¾ miles east of Barnesboro, on the Walnut Run branch of the Pennsylvania Railroad.

Coal bed.—Lower Kittanning, Miller, or B. Carboniferous age, Allegheny formation. Average thickness, 2 feet 10 inches. Roof, shale 3 to 18 feet thick, overlain by bony coal and sandstone; floor, smooth hard fire clay.

The bed was measured and sampled at five points in the mine by E. W. Miller on June 8, 1911, as described below:

Sections of coal bed in Cymbria mine.

Section	A		B		C		D		E	
Laboratory No	W20394		W20395		W20444		W20445		W20446	
Roof, sandstone, bony coal, and shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	2½	2	0	0	4½	1	0	2	11
Mother coal, soft	..	..	0	½	..	..	..	..	..	..
"Sulphur"	0	¼	..	..	[a]0	¼	0	¼	..	..
Coal	2	¼	0	7	0	6¼	0	7¼	..	..
"Sulphur"	[a]0	¾	..	..	0	¼	0	¼	..	..
Coal	0	6¼	..	..	0	7¼	0	9¼	..	..
"Sulphur"	..	..	..	..	0	¼	..	..	..	..
Coal	..	..	..	..	0	10	..	..	..	..
Floor, fire clay.										
Thickness of bed	2	10½	2	7½	2	4⅝	2	5	2	11
Thickness of coal sampled.	2	9¾	2	7½	2	4¼	2	5	2	11

[a] Not included in sample.

Section A (sample W20394) was measured at the face of second right entry, about 1,000 feet southwest of the shaft.

Section B (sample W20395) was measured near the face of room 18, off second left entry, about 1,200 feet northeast of the shaft.

Section C (sample W20444) was measured at the face of the main heading, 1,900 feet from the shaft.

Section D (sample W20445) was measured at the face of third left entry, about 1,400 feet northeast of the shaft.

Section E (sample W20446) was measured at the face of third right entry, about 1,200 feet southeast of the shaft.

A composite sample was made by combining face samples W20394, W20395, W20444, W20445, and W20446. The results of an ultimate analysis of this sample are given under laboratory No. 12372.

Notes.—At the time of sampling the coal was undercut with machines and shot down with FFFF black powder. There were no screens, the entire output being shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track at the tipple with a capacity of 48 cars. The mine had a capacity of 300 tons a day and an average daily output of 150 tons, all from advance workings. There were between 600 and 700 acres of unmined coal.

BARNESBORO. CYMBRIA NO. 1 MINE.

Sample.—Bituminous coal; Windber field; analyses Nos. 12162, 12163, 12164, 12165, 12170, and 12171 (p. 70).

Mine.—Cymbria No. 1, a slope mine in the Clearfield district, 2 miles east of Barnesboro, on the Cresson division of the Pennsylvania Railroad.

Coal bed.—Lower Freeport or D; Carboniferous age, Allegheny formation. Average thickness, 3 feet 6 inches. Roof, smooth dark shale; floor, hard smooth clay. Material from the roof and floor did not become mixed with the coal in mining.

The bed was measured and sampled at three points in the mine on April 28, 1911, and at two points on May 1, 1911, by H. I. Smith, as described below:

Sections of coal bed in Cymbria No. 1 mine.

Section	A		B		C		D		E	
Laboratory No.	12162		12163		12164		12170		12171	
Roof, sandstone and dark shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Bony shale	[a] 0	2	[a] 0	1	[a] 0	2½	[a] 0	2	[a] 0	2
Coal	1	0	0	8½	2	0	1	10	3	2½
Mother coal and "sulphur"	..	..	[a] 0	½	..	..	0	½	..	..
Coal	0	10	1	0	..	..	..	..	..	..
"Sulphur" and mother coal	[a] 0	½	[a] 0	¼	..	..	..	..	..	..
Coal	0	5	1	3	1	4½	0	8	..	..
Coal, bony	0	½	..	..	..	..	0	1	..	..
Coal	0	10½	..	..	..	..	1	0	..	..
Coal	..	..	[a] 0	1½	..	..	..	..	..	..
"Mining slate"	[a] 0	1	[a] 0	1¾	[a] 0	¾	[a] 0	1½	[a] 0	¾
Coal	[a] 0	½	..	..	..	..	..	..	..	..
Coal	0	11	0	7	0	11⅜	0	8	0	10¼
Floor, hard clay.										
Thickness of bed	4	5	3	11½	4	7⅛	4	1⅜	4	3¼
Thickness of coal sampled	4	1	3	6½	4	3⅞	3	10¼	4	¾

[a] Not included in sample.

Section A (sample 12162) was measured at the face of the first crosscut off left entry 2, 5,500 feet from the mine mouth.

Section B (sample 12163) was measured at the face of the eighth right off left entry 2, about 4,000 feet from the mine mouth.

Section C (sample 12164) was measured at the face of the first left off left entry 2, 4,000 feet from the mine mouth.

Section D (sample 12170) was measured at the face of the third right off the second main entry, about 3,200 feet northeast of the mine mouth.

Section E (sample 12171) was measured at the face of the second left off the main heading, 2,900 feet northeast of the drift mouth.

A composite sample was made by combining face samples 12162, 12163, 12164, 12170, and 12171. The results of an ultimate analysis of this sample are given under laboratory No. 12165.

Notes.—At the time of sampling the coal was undercut by chain machines and also by hand. The undercut coal was broken down with FFFF black powder. A permissible explosive was used for brushing the roof and floor. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. The tipple had two loading tracks, with a capacity of 25 empty and 35 loaded cars. The coal from Cymbria No. 1 and Cymbria No. 2½ mines went to the same tipple, and the combined capacity of the two mines was 800 tons a day with an average daily output of 600 tons, 66 per cent of which was from advance workings and the remainder from pillars. There was approximately 175 acres of unmined coal.

BARNESBORO. CYMBRIA No. 2½ MINE.

Sample.—Bituminous coal; Windber field; analyses Nos. 12158, 12159, 12160, 12161, 12172, and 12173 (pp. 70, 71).

Mine.—Cymbria No. 2½, a slope mine in the Clearfield district, 2 miles east of Barnesboro, on the Cresson division of the Pennsylvania Railroad.

Coal bed.—Upper Freeport or E. Carboniferous age, Allegheny formation. Average thickness, 3 feet 6 inches. Roof, a dark, smooth shale, above which is a sandstone cap rock; floor, a smooth, hard clay.

The bed was measured and sampled at three points in the mine by H. I. Smith on April 28, 1911, and at two points on May 1, 1911, as described on the following page.

Sections of coal bed in Cymbria No. 2½ mine.

Section	A		B		C		D		E	
Laboratory No	12158		12159		12160		12172		12173	
Roof, sandstone, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	..	..	..	..	0	2	..	..	..	..
Coal, bony	..	..	..	..	0	⅛	..	..	..	..
Coal	..	..	..	..	0	4	..	..	..	..
Coal, bony	*a* 0	½	..	..	0	⅛	*a* 0	½	*a* 0	½
Coal (brittle)	1	5	1	9	0	10	1	6	0	3½
"Sulphur" and mother coal	0	¼	..	..	*a* 0	¼	0	⅜	0	¼
Coal (firm)	1	2½	0	11	1	1½	1	½	1	7½
Mother coal	..	..	..	..	..	..	..	..	0	¼
Coal	..	..	..	..	..	..	..	..	0	10
Coal	..	..	*a* 0	1	*a* 0	½	..	..	..	..
"Slate binder"	*a* 0	1	*a* 0	½	*a* 0	1½	*a* 0	2	*a* 0	1
Coal	*a* 0	1½	*a* 0	1	*a* 0	¾	..	..	..	..
Coal	0	9	0	9	0	11	0	10	0	10½
Floor, hard fire clay.										
Thickness of bed	3	7¾	3	7½	3	7¾	3	7⅜	3	9½
Thickness of coal sampled	3	4¾	3	5	3	4¾	3	4⅞	3	8

a Not included in sample.

Section A (sample 12158) was measured at the face of left entry 2, about 2,000 feet from the mine mouth.

Section B (sample 12159) was measured at the face of room 12 off the main heading, 2,200 feet from the mine mouth.

Section C (sample 12160) was measured at the face of the third left main heading.

Section D (sample 12172) was measured at the face of room 6 off the main heading, 1,500 feet southwest of the mine mouth.

Section E (sample 12173) was measured at the face of room 8 off the second left heading, 1,200 feet southwest of the mine mouth.

A composite sample was made by combining face samples 12158, 12159, 12160, 12172, and 12173. The results of an ultimate analysis of this sample are shown under laboratory No. 12161.

Notes.—As Cymbria No. 1 mine and Cymbria No. 2½ mine use the same tipple, the notes on Cymbria No. 1 are applicable to Cymbria No. 2½.

BARNESBORO. EMPIRE A MINE.

Sample.—Bituminous coal; Windber field; analyses Nos. 12212, W19643, W19644, W19645, W19646, W19647, and W19648 (p. 71).

Mine.—Empire A, a drift mine in the Clearfield district, three-fourths of a mile west of Barnesboro, on the New York Central and the Pennsylvania Railroad.

Coal bed.—Lower Freeport or D. Carboniferous age, Allegheny formation. Average thickness, 4 feet 4 inches. Roof, shale; between the shale and the coal is a stratum of cannel coal about 2 inches thick. Floor, hard smooth fire clay. Material from the roof and floor did not become mixed with the coal in mining.

The bed was measured and sampled at six points in the mine by P. M. Riefkin on April 28, 1911, as described below:

Sections of coal bed in Empire A mine.

Section	A		B		C		D		E		F	
Laboratory No	W19643		W19644		W19645		W19646		W19647		W19648	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Cannel coal	*a* 0	2	*a* 0	2	*a* 0	1½	*a* 0	2	*a* 0	1	*a* 0	2
Coal	0	7	0	3½	0	7	0	8	0	6¼	0	7
Coal, bony, and shale	*a* 0	1½	..	..	..	..	*a* 0	½	*a* 0	⅞	*a* 0	1
Coal, hard, gray	..	..	0	1	..	..	..	..	..	..	..	..
Coal	1	2	1	10	..	..	1	1¾	0	5¾	1	1
Mother coal	0	¼	0	½	Streak.		0	¼	Streak.		0	½
Coal	0	8½	1	1	2	2	0	10	1	7½	1	10½
Mother coal	0	½	..	..	0	¼	0	¼	0	⅜	..	..
Coal	0	9½	..	..	0	7	0	7¾	0	2½	..	..
Shale	*a* 0	1	*a* 0	1¾	*a* 0	¾	*a* 0	⅞	*a* 0	1	*a* 0	1
Coal	0	8½	0	11	0	10	0	8½	0	8	0	11½
Floor, hard fire clay.												
Thickness of bed	4	4¾	4	6¾	4	4½	4	3⅞	3	9¼	4	10½
Thickness of coal sampled	4	¼	4	3	4	2¼	4	½	3	6⅜	4	6½

a Not included in sample.

Section A (sample W19643) was measured in room 1 off left entry 5 off new parallel heading, 14,000 feet northwest of the drift mouth.

Section B (sample W19644) was measured near the face of room 4 off old first left heading off the main entry, 2,000 feet northwest of the drift mouth.

Section C (sample W19645) was measured at the corner of the back heading on right entry 3 off the old parallel heading, 3,000 feet northeast of the drift mouth.

Section D (sample W19646) was measured 40 feet from the face of the parallel heading off the main entry, 9,000 feet northeast of the drift mouth.

Section E (sample W19647) was measured at the face of room 24 off left entry 14 off the main entry, 11,000 feet northwest of the drift mouth.

Section F (sample W19648) was measured at the face of room 17 off left entry 3 off the new parallel heading, 14,000 feet northwest of the drift mouth.

A composite sample was made by combining face samples W19643 to W19648, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 12212.

Notes.—At the time of sampling the coal was undercut by compressed-air punchers and broken down with FFFF black powder. There was one loading track at the tipple, and the entire production was shipped as run-of-mine. Pickers were employed on the car in loading. The mine had a capacity of about 1,000 tons a day, with an average daily output of 625 tons, 75 per cent of which was from advance workings. There were approximately 750 acres of unmined coal.

BEAVERDALE. PENNSYLVANIA NO. 15 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12174, 12175, 12176, 12177, 12178, and 12179 (p. 71).

Mine.—Pennsylvania No. 15, a shaft mine in the Clearfield district, at Beaverdale, on the South Fork branch of the Pennsylvania Railroad.

Coal bed.—Lower Kittanning or B; Carboniferous age, Allegheny formation. Thickness, 3 feet to 3 feet 8 inches; dip, 3° north. Roof, bony coal, 5 inches thick, with sandstone cap rock; floor, hard smooth fire clay. Material from the roof and floor did not mix with the coal in mining.

The bed was measured and sampled at five points in the mine by E. G. Borden on May 1, 1911, as described below:

Sections of coal bed in Pennsylvania No. 15 mine.

Section	A		B		C		D		E	
Laboratory No.	12174		12175		12176		12177		12179	
Roof, sandstone, and bony coal.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in*
Coal	0	2	..	..	..	..	0	3½	0	6½
Mother coal	0	¼	..	..	..	..	..	..	..	..
Coal	1	7	..	..	..	..	..	..	..	..
Coal, gray	..	..	..	..	..	..	..	..	0	1½
"Sulphur"	Streak.		..	..	..	..	Streak.		..	..
Coal	1	1½	2	9	3	4	3	¼	2	5
Mother coal	0	¼	0	½	..	..	..	..	..	..
Coal	0	4	0	7	..	..	..	..	..	..
Floor, hard fire clay.										
Thickness of bed	3	3	3	4½	3	4	3	3¾	3	1
Thickness of coal sampled	3	3	3	4½	3	4	3	3¾	3	1

Section A (sample 12174) was measured near the face of the first slant off right heading 5 off the first dip off the main entry.

Section B (sample 12175) was measured at the face of the sump for the main dip, off left heading 4 off the first dip off the main entry.

Section C (sample 12176) was measured at the face of the first slant off right heading 4 off the first dip off the main entry.

Section D (sample 12177) was measured at the face of the first slant off right heading 3 off the first dip off the main entry.

Section E (sample 12179) is a pillar sample taken in room 23 off right heading 3 off the first dip off the main entry.

A composite sample was made by combining face samples 12174 to 12177, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 12178.

Notes.—The shaft is 624 feet deep. At the time of sampling the coal was undercut with compressed-air punching machines and broken down with black powder. Dynamite was used for brushing the roof and floor. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. There were two loading tracks at the tipple with a capacity of 25 empty and 22 loaded cars. The daily output was 450 tons, about 80 per cent of which was from advance workings.

BENS CREEK. BENS CREEK NO. 1 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12211, W19697, W19700, W19702, W19736, and W19737 (p. 72).

Mine.—Bens Creek No. 1, a shaft mine in Portage township, 1 mile east of Bens Creek, on the Bens Creek branch of the Pennsylvania Railroad.

Coal bed.—Lower Kittanning, Miller, or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet 6 inches. Roof, hard gray smooth shale; floor, smooth hard shale, underlain by fire clay.

The bed was measured and sampled at five points in the mine by E. W. Miller on May 2, 1911, as described below:

Sections of coal bed in Bens Creek No. 1 mine.

Section	A		B		C		D		E	
Laboratory No	W19697		W19700		W19702		W19736		W19737	
Roof, shale and bony coal.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	0	1	9¾	..	..	..	..	0	5¼
"Sulphur" streak	0	⅛	0	⅛	..	..	..	..	0	⅛
Coal	1	6½	0	7½	3	9	3	4	3	2⅜
"Sulphur" streak	..	..	0	⅛	..	..	..	..	..	..
Coal	..	..	0	8	..	..	..	..	..	..
Floor, shale and fire clay.										
Thickness of bed	3	6⅝	3	1½	3	9	3	4	3	7¾
Thickness of coal sampled	3	6⅝	3	1½	3	9	3	4	3	7¾

Section A (sample W19697) was measured on the barrier pillar on No. 2 sidetrack, 100 feet from room 21 and 3,200 feet southwest of the old main heading.

Section B (sample W19700) was measured on the pillar on No. 1 sidetrack between the manway and room 1, 1,200 feet southwest of the shaft.

Section C (sample W19702) was measured on the main pillar of the old main heading, 900 feet southwest of the shaft.

Section D (sample W19736) was measured at the face of heading 6, off the first dip, 700 feet southeast of the shaft.

Section E (sample W19737) was measured on the pillar of heading 1, between rooms 27 and 28, 2,700 feet southwest of the shaft.

A composite sample was made from face samples W19697, W19700, W19702, and W19737. The results of an ultimate analysis of this sample are shown under laboratory No. 12211.

Notes.—At the time of sampling the coal was undercut by hand and shot down with black powder. There were no screens, the entire output being shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track at the tipple with a capacity of 24 cars. The mine had a capacity of 230 tons a day and an average daily output of about 225 tons, all from pillar workings.

BENS CREEK. PENNSYLVANIA No. 2 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. W19695, W19696, W19698, W19699, W19701, and 12222 (pp. 72, 73).

Mine.—Pennsylvania No. 2, a slope mine 1 mile south of Bens Creek, on the Bens Creek branch of the Pennsylvania Railroad.

Coal bed.—Lower Kittanning, Miller, or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet 6 inches. Roof, shale overlain by sandstone cap rock; floor, smooth shale underlain by fire clay.

The bed was measured and sampled at five points in the mine by E. W. Miller on May 1, 1911, as described below:

Sections of coal bed in Pennsylvania No. 2 mine.

Section	A		B		C		D		E	
Laboratory No	W19695		W19696		W19698		W19699		W19701	
Roof, sandstone, shale, and bony coal.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	6	1	¾	1	3	1	0	1	2½
Mother coal, hard	0	¾	0	½	0	¾	0	½	0	¾
Coal	0	6¾	0	9½	2	4	2	4½	0	6
"Sulphur" streak	[a]0	¼	0	¼	..	..	..	..	0	¼
Coal	0	8½	0	7¾	..	..	..	..	0	3½
"Sulphur" streak	[a]0	½	0	⅜	..	..	..	..	0	¼
Coal	0	8¾	0	5	..	..	..	..	1	5
"Sulphur" ball	[a]0	1	..	..	..	..	..	..	..	..
Coal	0	1	..	..	..	..	..	..	..	..
Shale	..	..	[a]0	½	..	..	..	..	..	..
Coal	..	..	0	3	..	..	..	..	..	..
Floor, shale and fire clay.										
Thickness of bed	3	9½	3	3⅝	3	7¾	3	5	3	6¼
Thickness of coal sampled	3	7¾	3	3⅛	3	7¾	3	5	3	6¼

[a] Not included in sample.

Section A (sample W19695) was measured at the face of heading 19, 4,100 feet northeast of the drift mouth.

Section B (sample W19696) was measured on the pillar between rooms 14 and 15 off main heading 4, 2,900 feet northwest of the drift mouth.

Section C (sample W19698) was measured on the pillar between rooms 2 and 3 off butt entry 17, 3,900 feet north of the drift mouth.

Section D (sample W19699) was measured on the pillar between rooms 1 and 2 off butt entry 16, 3,900 feet north of the drift mouth.

Section E (sample W19701) was measured on the pillar between rooms 21 and 22 off heading 5, 3,200 feet north of the drift mouth.

Notes.—At the time of sampling the coal was undercut by hand and shot down with black powder. About 90 per cent of the coal was shipped as run-of-mine; the remaining 10 per cent was passed over 8-foot bar screens with 4-inch openings. Pickers were employed on the cars in loading. There were two loading tracks with a capacity of 25 cars. The mine was equipped to produce 200 tons a day and had an average daily output of 175 tons, practically all of which was from pillar workings. The intent was to increase the output to about 200 tons.

CARROLLTOWN ROAD. LOGAN No. 5 MINE.

Sample.—Bituminous coal; Windber field; analyses Nos. 12370, W20364, W20365, W20366, W20367, and W20368 (p. 73).

Mine.—Logan No. 5, a drift mine one-fourth of a mile west of Carrolltown Road, on the Cresson division of the Pennsylvania Railroad.

Coal bed.—Miller. Carboniferous age, Allegheny formation. Average thickness, 2 feet 8 inches. Roof, hard shale overlain by bony coal and sandstone; floor, smooth, hard fire clay.

The bed was measured and sampled at five points in the mine by E. W. Miller on June 7, 1911, as described on the following page.

Sections of coal bed in Logan No. 5 mine.

Section	A		B		C		D		E	
Laboratory No	W20364		W20365		W20366		W20367		W20368	
Roof, sandstone, bony coal, and shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	6	0	6¾	1	10	0	6½	0	5
"Sulphur" streak	0	⅛	0	1/16	0	⅛	0	⅛	0	⅛
Coal	0	7	1	½	0	8	1	9⅞	0	7½
"Sulphur" streak	0	⅛	0	¼	..	..	..	..	0	⅛
Coal	1	5¼	0	10	..	..	..	..	1	5¾
Floor, fire clay.										
Thickness of bed	2	6½	2	5 9/16	2	6⅛	2	4½	2	6½
Thickness of coal sampled	2	6½	2	5 9/16	2	6⅛	2	4½	2	6½

Section A (sample W20364) was measured in the first main heading, 4,300 feet south of the mine mouth.

Section B (sample W20365) was measured at the face of right entry 2; 250 feet from the second main heading and 3,750 feet south of the mine mouth.

Section C (sample W20366) was measured at the face of room 8 off the air course of right entry 1, off the second main entry, 4,300 feet south of the mine mouth.

Section D (sample W20367) was measured at the face of the second main heading, 3,600 feet southeast of the mine mouth.

Section E (sample W20368) was measured at the face of the fourth left heading off the second main heading, 3,200 feet southeast of the mine mouth.

A composite sample was made by combining face samples W20364 to W20368, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 12370.

Notes.—At the time of sampling the coal was undercut both by hand and with machines, and shot down with black powder. There were no screens, the output being shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track at the tipple with a capacity of 50 cars. The mine had a capacity of 600 tons a day with an average daily output of about 350 tons, all of which was from advance workings. The intent was to increase the production to about 700 tons a day. There were approximately 700 acres of unmined coal.

COLVER. COLVER MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 13634 to 13643, inclusive (p. 73).

Mine.—Colver, a drift mine, in the Ebensburg district, at Colver, the terminus of the Cambria & Indiana Railroad.

Coal bed.—Known as the Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, 4 feet. Roof, hard gray shale, with smooth surface; floor, shaly underclay with a smooth surface.

The bed was measured and sampled at nine points in the mine by L. M. Jones, on March 28 and 29, 1912, as described below:

Sections of coal bed in Colver mine.

Section	A		B		C		D		E		F	
Laboratory No	13634		13635		13636		13637 13643		13638 13642		13639 13641	
Roof, gray shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, bony	[a]0	3	[a]0	3	[a]0	3	[a]0	5	[a]0	4	[a]0	5
Coal, soft	1	1	2	8½	2	1⅜	3	10	2	4½	0	9
Coal, dull	..	..	..	..	..	..	..	..	..	..	0	¾
Shale	0	¼	..	..	..	..	..	..	0	½	..	..
Coal, soft	1	0	..	..	..	..	..	..	..	..	1	¾
"Sulphur" band	[a]0	¼	[a]0	½	[a]0	½	..	..	..	..	[a]0	½
Coal	0	5¼	1	1½	1	8⅛	..	..	1	1½	1	8¾
Shale	0	¼	..	..	..	..	..	..	..	..	..	..
Coal	1	1	..	..	..	..	..	..	..	..	..	..
Floor, shaly underclay.												
Thickness of bed	3	11	4	1½	4	2	4	3	3	10	4	1
Thickness of coal sampled	3	7¾	3	10	3	10½	3	10	3	6	3	7½

[a] Not included in sample.

Section A (sample 13634) was cut from the face of main entry A, 2,400 feet southwest of bore hole 25.

Section B (sample 13635) was cut from the face of entry A-2, 1,175 feet southeast from bore hole 25.

Section C (sample 13636) was cut from the face of entry A-3, 1,400 feet south of bore hole 25.

Section D (duplicate samples 13637 and 13643) was cut from the face of the main entry, 1,200 feet southeast of bore hole 25.

Section E (duplicate samples 13638 and 13642) was cut from the face of entry B-1), 725 feet southeast of bore hole 25, at the inner end of the rock tunnel.

Section F (duplicate samples 13639 and 13641) was cut from the face of entry A-1, 950 feet southeast of bore hole 25.

A composite sample was made by mixing samples 13634 to 13639 inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 13640.

Notes.—This mine was originally opened by a slope and shaft but at the time of sampling all the coal shipped was hauled to the surface through a rock tunnel 2,050 feet long.

The steel tipple was designed to handle 4,000 tons of coal a day. There were two loading tracks with a capacity of 80 empty cars. The tipple was equipped with a shaking screen having perforations 1¼ inches in diameter, but the entire output was shipped as run-of-mine.

The coal was undercut with chain cutting machines and with punching machines and shot down with FFFF black powder. The impurities that might be loaded with the coal were a bony coal at the top of the seam, which in places stuck to the roof, and a "sulphur" band below the middle. The roof and floor were hard and generally smooth and were not likely to get mixed with the coal.

The average daily output, the mine working double shifts, was 1,000 tons. There was 8,000 acres of coal land at this mine, the development of which was still in an early stage. The maximum day's run was 1,040 tons

DUNLO. HENRIETTE MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 14238 to 14246, inclusive (p. 74).

Mine.—Henriette, a shaft mine 1 mile south of Dunlo, on the South Fork branch of the Pennsylvania Railroad, with connections to the main line at South Fork.

Coal bed.—Miller or B. Carboniferous age, Allegheny formation. Thickness, about 3 feet 8 inches; dip, 7½° northwest. Roof, smooth shale 1 to 10 feet thick, above which is a sandstone cap rock. Floor, hard, smooth fire clay. The parting between the floor and the coal and the roof is distinct, so that neither the floor or the roof material got mixed with the coal in mining. Cover at points of sampling, 130 to 400 feet.

The bed was measured and sampled at five points in the mine by A. H. Fay, on June 27, 1912, as described below:

Sections of coal bed in Henriette mine.

Section	A	B	C	D	E
Laboratory No	14245 14238	14246 14239	14244 14240	14241	14242
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Top coal or bone	0 4	0 3	0 2	0 3½	.. ..
Coal	3 5½	3 7	3 4½	3 4	3 8
Floor, shale and fire clay.					
Thickness of bed	3 9½	3 10	3 6½	3 7½	3 8

Section A (sample 14238 is the good coal and sample 14245 is the bone or top coal) was measured on the rib of room 2, right heading 1 off slope 2, about 700 feet north of shaft No. 2.

Section B (sample 14239 is the good coal and sample 14246 is the bone or top coal) was measured at the junction of the sixth slant and main heading, about 3,050 feet north of shaft No. 2.

Section C (sample 14240 is the good coal and sample 14244 is the bone or top coal) was measured on the pillar of sixth left entry near room 13, north of the rock fault, 4,350 feet northwest of shaft No. 2.

Section D (sample 14241) was measured on the pillar of sixth left heading, 450 feet north of the back heading of slope 2 and 4,150 feet northwest of shaft No. 2.

Section E (sample 14242) was measured on the rib between rooms 1 and 2, first level above the main entry, about 1,500 feet northwest of shaft No. 2.

A composite sample was made by combining samples 14238 to 14242, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14243.

Notes.—The mine is opened by a shaft 90 feet deep, from the bottom of which a slope extended a distance of about 7,000 feet. The coal is mined by the room-and-pillar system. That part of the mine from which these samples were taken had been practically abandoned for a number of years, and at the time of sampling no mining was being done there. It was proposed to pull the pillars later. Other property tributary to this slope was producing about 700 tons a day. All of the coal was shipped as run-of-mine. Pickers were employed on the car in loading. The coal is somewhat friable and does not yield extra large lumps. There were two loading tracks with a capacity of 25 to 30 cars.

EL MORA. PEERLESS NO. 1 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12134, 12135, 12136, 12137, 12138, and 12139 (p. 75).

Mine.—Peerless No. 1, a drift mine in Carroll Township, near El Mora on the Pennsylvania Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, about 3 feet; dip, about 3°. The immediate roof is a "draw slate" about 18 inches thick, above which there is a sandstone cap rock. Floor, hard rough fire clay. The bed was measured and sampled at five points in the mine by P. M. Riefkin on April 27, 1911, as described below:

Sections of coal bed in Peerless No. 1 mine.

Section	A		B		C		D		E	
Laboratory No	12134		12135		12136		12137		12138	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, hard	0	4	0	5	..	..	0	5½	0	5½
Coal	0	4	..	..	..	..	0	8½	..	..
Bone	0	⅛	0	⅛	..	..	..	..	..	..
Mother coal	..	..	..	..	..	..	0	½	..	..
Coal	2	5	2	7	2	9	0	9	..	..
"Sulphur"	0	¼	..	..	[a]0	½	0	¼	0	¼
Coal	0	2½	..	..	0	2	1	0	2	5½
Floor, fire clay.										
Thickness of bed	3	3⅞	3	⅛	2	11½	2	11¾	2	11¼
Thickness of coal sampled	3	3⅞	3	⅛	2	11	2	11¾	2	11¼

[a] Not included in sample.

Section A (sample 12134) was measured on a heading stump on left heading 3 off the main entry, about 1,700 feet northeast of the drift mouth.

Section B (sample 12135) was measured at the face of room 1, off right heading 8 off the main entry, 2,300 feet east of the drift mouth.

Section C (sample 12136) was measured at the face of left heading 7 off the main entry, about 2,800 feet northeast of the drift mouth.

Section D (sample 12137) was measured on the rib of room 1, off right heading 3 off the main heading, 1,600 feet southeast of the drift mouth.

Section E (sample 12138) was measured in heading 1 off the main entry, about 425 feet from the main entry.

A composite sample was made by combining face samples 12134 to 12138, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 12139.

Notes.—The mine is opened by entry; the cover at the opening is 40 feet. The room-and-pillar method of mining is used. At the time of sampling FFFF black powder was used for breaking the coal. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. The mine had a daily output of about 125 tons a day, 75 per cent of which was from advance workings and the remainder from pillars.

FIGART. FRICK NO. 2 MINE.

Sample.—Bituminous coal; Windber field; analyses Nos. 12366, W20433, W20434, W20474, W20475, and W20476 (p. 75).

Mine.—Frick No. 2, a drift mine 1¼ miles northeast of Figart, on the Pennsylvania Railroad.

Coal bed.—C or Middle Kittanning. Carboniferous age, Allegheny formation. Average thickness, 2 feet 7 inches. Roof, dark shale; floor, medium soft fire clay with a smooth surface. The B bed, or Lower Kittanning, is also worked at this mine, and the coal is delivered to the same tipple as is the coal from the C bed.

The C bed was measured and sampled at five points in the mine by H. I. Smith on June 10, 1911, as described below.

Sections of coal bed in Frick No. 2 mine.

Section	A		B		C		D		E	
Laboratory No	W20433		W20434		W20474		W20475		W20476	
Roof, dark shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, bony	[a]0	8	[a]0	9½	[a]0	10½	[a]0	9	[a]0	10
Coal	1	3½	1	3½	0	4½	0	6	1	3
Coal, gray	..	..	..	..	0	1	0	½	..	..
Shale	0	¼	..	..	..	..	..	..	..	..
Coal	0	1	..	..	0	8¾	0	10	..	..
Cannel coal	0	1	0	1	[a]0	3	0	½	[a]0	2
Coal, bony	[a]0	1	..	..	..	..	..	..	..	..
Coal	0	9	0	9	0	10½	0	11	0	8½
Coal streaked with "sulphur"	[a]0	2½	([b])		..	..	..	..	..	..
Coal	..	..	0	2	..	..	..	..	..	..
Floor, fire clay.										
Thickness of bed	3	2¼	3	1	3	2¼	3	1	2	11½
Thickness of coal sampled	2	2¾	2	3½	2	¾	2	4	1	11½

[a] Not included in sample. [b] "Sulphur" streak.

Section A (sample W20433) was measured at the face of the second main heading, 400 feet from the mouth of the main entry.

Section B (sample W20434) was measured at the face of entry 1, off the second main heading, 400 feet from the mouth of the main entry.

Section C (sample W20474) was measured at the face of room 5, off the main left heading, 850 feet from the mouth of the main entry.

Section D (sample W20475) was measured at the face of the first left heading, 500 feet from the mouth of the main entry.

Section E (sample W20476) was measured at the face of the straight main heading, 1,200 feet from the mouth of the entry.

A composite sample was made by combining face samples W20433, W20434, W20474, W20475, and W20476. The results of an ultimate analysis of this sample are shown under laboratory No. 12366.

Notes.—At the time of sampling the coal was undercut by hand and shot down with FFFF black powder. There were no screens, the entire output being shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track with a capacity of 28 cars. The mine had a capacity of 100 tons and an average daily output of 80 tons, of which the larger part was from advance workings. There were approximately 50 acres of unmined coal tributary to this opening.

HASTINGS. MILLER RUN MINE.

Sample.—Bituminous coal; Windber field; analyses Nos. 12371, W20440, W20441, W20442, W20443, and W20447 (p. 76).

Mine.—Miller Run, a drift mine 2½ miles northeast of Hastings, on the Cresson division of the Pennsylvania Railroad.

Coal bed.—Miller or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet. Roof, shale overlain by sandstone; floor, smooth fire clay.

The bed was measured and sampled at five points in the mine by E. W. Miller on June 9, 1911, as described below:

Sections of coal bed in Miller Run mine.

Section	A		B		C		D		E	
Laboratory No.	W20440		W20441		W20442		W20443		W20447	
Roof, sandstone and shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	7	0	5	..	..	0	2	0	1½
Coal, bony	[a]0	9½	..	..	..	..	..	..	..	..
"Sulphur"	..	..	..	..	..	..	0	⅛	..	..
Coal	0	3½	..	..	..	..	0	2½	..	..
Mother coal	0	¼	..	..	..	..	..	..	..	..
"Sulphur" ball	..	..	..	..	..	..	0	¼	0	½
Coal	..	..	..	..	..	..	0	1½	0	5
Coal, bony	..	..	[a]0	10	[a]1	4½	[a]0	9	[a]0	8
Coal	1	2½	1	3½	1	2	1	5½	1	4
"Sulphur"	[a]0	½	..	..	..	..	..	..	..	..
Coal, bony	..	..	0	¾	0	¼	0	¾	0	½
Coal	1	1¾	1	6½	1	6¼	1	4	1	4
Floor, fire clay.										
Thickness of bed	4	1	4	1¾	4	1	4	1⅝	3	11½
Thickness of coal sampled	3	3	3	3¾	2	8½	3	4⅝	3	3½

[a] Not included in sample.

Section A (sample W20440) was measured at the face of the main air course, 2,000 feet from the drift mouth.

Section B (sample W20441) was measured at the face of room 4, off the fifth right entry, 200 feet from the main entry.

Section C (sample W20442) was measured at the face of the first right entry, 200 feet off left entry 2.

Section D (sample W20443) was measured at the face of the second left entry, 500 feet off the main entry.

Section E (sample W20447) was measured on pillar of room 5, first left entry, 300 feet off the main entry.

A composite sample was made by mixing face samples W20440 to W20443. The results of an ultimate analysis of this sample are shown under laboratory No. 12371.

Notes.—At the time of sampling the coal was undercut by hand and shot down with FFF black powder. There were no screens, the entire output being shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track at the tipple with a capacity of 8 empty and 8 loaded cars. The mine was equipped to produce 200 tons a day and had an average daily output of 100 tons, of which the larger part was from advance workings. The intent was to increase the output to 200 tons in the near future. There were 129 acres of unmined coal tributary to this opening.

HASTINGS. PENNSYLVANIA NO. 11 AND NO. 12 MINES.

Sample.—Bituminous coal; Windber field; analyses Nos. 12150 to 12157, inclusive, and 12166 to 12169, inclusive (pp. 76, 77).

Mines.—Pennsylvania No. 11 and Pennsylvania No. 12, drift mines in the central Pennsylvania district, 1 mile south of Hastings, on the Cresson division of the Pennsylvania Railroad.

Coal bed.—Lower Freeport or D, Carboniferous age, Allegheny formation. Average thickness, 4 feet 4 inches. Roof, dark shale, overlain by sandstone; floor, hard rough fire clay. Particles of the roof or floor did not become mixed with the coal in mining.

The bed was measured and sampled at five points in the No. 11 mine and at five points in the No. 12 mine by H. I. Smith, April 29, 1911, as described below:

Sections of coal bed in Pennsylvania No. 11 mine.

Section	A		B		C		D		E	
Laboratory No.	12150		12151		12166		12167		12169	
Roof, shale and sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Shale	[a]0	2½	[a]0	2	[a]0	2¼	[a]0	2	[a]0	2
Coal	1	6	1	1	2	10	2	0	0	11
Mother coal and "sulphur"	0	⅜	0	¼	..	..	..	..	0	½
Coal	2	8¼	2	3	0	4	1	1	2	2¼
"Mining slate" and coal	[a]0	2¼	[a]0	1½	[a]0	1	[a]0	1½	[a]0	2½
Coal	0	8	1	½	0	7	0	3½	0	10½
Floor, fire clay.										
Thickness of bed	5	3⅜	4	8¼	4	¼	3	8	4	4¾
Thickness of coal sampled	4	10⅝	4	4¾	3	9	3	4½	4	¼

[a] Not included in sample.

Section A (sample 12150) was measured at the face of fifth right entry, off the main heading.

Section B (sample 12151) was measured at the face of the old main heading.

Section C (sample 12166) was measured at the face of the second right cross heading.

Section D (sample 12167) was measured at the face of left heading 3.

Section E (sample 12169) was measured on the pillar in room 16, off third left entry.

A composite sample was made by combining face samples 12150, 12151, 12166, and 12167. The results of an ultimate analysis of this sample are shown under laboratory No. 12168.

Sections of coal bed in Pennsylvania No. 12 mine.

Section	A		B		C		D		E	
Laboratory No.	12152		12153		12154		12155		12156	
Roof, shale and sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Shale	..	..	[a]0	1	[a]0	1½	[a]0	1	[a]0	2
Coal	2	6	0	8	3	2¼	1	6	2	5
Coal, bony	..	..	[a]0	¼	..	..	..	..	[a]0	1
Coal	..	..	1	5	..	..	..	..	0	5
Mother coal and "sulphur"	..	..	0	⅛	..	..	0	¼	0	½
Coal	..	..	1	4½	..	..	1	10½	0	5½
"Mining slate" and coal	[a]0	1½	[a]0	¾	[a]0	2	[a]0	1¼	[a]0	3
Coal	0	6	0	5	0	6	0	9½	0	5
Floor, fire clay.										
Thickness of bed	3	1½	4	⅝	3	11¾	4	4½	4	3
Thickness of coal sampled	3	0	3	10⅝	3	8¼	4	2¼	3	9

[a] Not included in sample.

Section A (sample 12152) was measured at the face of the original old main heading, 5,800 feet from the drift mouth.

Section B (sample 12153) was measured at the face of fifth entry, off the main heading.

Section C (sample 12154) was measured at the face of fourth right heading, 1½ miles from the drift mouth.

Section D (sample 12155) was measured at the face of room 1, off first entry off third right heading.

Section E (sample 12156) was measured at the face of third right entry, off the main heading.

A composite sample was made by combining face samples 12152 to 12156, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 12157.

Notes.—The system of mining in both mines is single entry, room-and-pillar. At the time of sampling the coal was undercut in the lower part of the bed by electric chain cutting machines and shot down with FFF and FFFF black powder. There was one loading track at the tipple with a capacity of 28 empty and 28 loaded cars. Pickers were employed on the cars in loading. The entire output of the mines was shipped as run-of-mine coal. The No. 11 mine was equipped to produce about 400 tons of coal a day and had a daily output of 325 tons. There was about 100 acres of coal tributary to this mine. The No. 12 mine was equipped to produce 300 tons a day. There was about 100 acres of coal tributary to this drift entry. All of the coal from these two mines was used for coking purposes. Both mines load over the same tipple.

JOHNSTOWN. VALLEY NO. 1 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12213, W19563, W19564, W19565, W19566, and W19567 (p. 77).

Mine.—Valley No. 1, a drift mine in the central Pennsylvania district, 3 miles south of Johnstown, on the Somerset & Cambria branch of the Baltimore & Ohio Railroad.

Coal bed.—C′ or Upper Kittanning. Carboniferous age, Allegheny formation. Average thickness, 4 feet 2 inches. Roof, bony coal overlain with shale; floor, rough shale.

The bed was measured and sampled at five points in the mine by E. W. Miller on April 27, 1911, as described below:

Sections of coal bed in Valley No. 1 mine.

Section	A		B		C		D		E	
Laboratory No.	W19563		W19564		W19565		W19566		W19567	
Roof, bony coal and shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	4¾	1	5	0	2¾	1	3½	0	5¼
Bone, shale, and "sulphur"	[a]0	¼	0	¼	0	⅛	[a]0	¾	0	⅛
Coal	2	7	2	8¾	3	6½	2	9½	3	3
Bone	..	..	..	..	..	..	..	..	[a]0	¼
Coal	..	..	..	..	..	..	..	..	0	7½
Floor, shale.										
Thickness of bed	4	0	4	2	3	9⅜	4	1¾	4	4⅛
Thickness of coal sampled	3	11¾	4	2	3	9⅜	4	1	4	3⅞

[a] Not included in sample.

Section A (sample W19563) was measured at the face of room 11 in Andy's heading, 1,000 feet west of tipple No. 2.

Section B (sample W19564) was measured at the face of room 21, off left heading 7, 3,400 feet southeast of the drift mouth. There are small "sulphur" concretions in this section.

Section C (sample W19565) was measured on the chain pillar, 4,200 feet northeast of the drift mouth.

Section D (sample W19566) was measured at the face of room 4, off eighth right heading 3,600 feet southeast of the drift mouth.

Section E (sample W19567) was measured on the rib of the main air course, 150 feet beyond twelfth right heading.

A composite sample was made by mixing face samples W19563, W19564, W19566, and W19567. The results of an ultimate analysis of this sample are shown under laboratory No. 12213.

Notes.—At the time of sampling the coal was undercut by hand and shot down with black powder. There were two tipples; each tipple had one loading track with a capacity of 50 cars. There were no screens, the entire output being shipped as run-of-mine. Pickers were employed on the cars in loading. The mine had a capacity of about 1,500 tons a day with an average daily output of 1,200 tons, 90 per cent of which was from advance workings.

NANTY GLO. LINCOLN NO. 1 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12180, 12181, 12182, 12183, 12184, and 12185 (p. 78).

Mine.—Lincoln No. 1, a drift mine in the central Pennsylvania district, 1 mile north of Nanty Glo on the Pennsylvania Railroad.

Coal bed.—Lower Kittanning, Miller, or B. Carboniferous age, Allegheny formation. Average thickness, about 3 feet 5 inches. The bed lies practically flat; the cleat is irregular. Roof, hard dark shale overlain by sandstone capping; floor, soft shale. All of the samples were taken at a depth of about 600 feet. There are occasionally small soft "sulphur" lenses in this coal. The bed was measured and sampled at five points in the mine by A. J. Hazlewood on May 3, 1911, as described below:

Sections of coal bed in Lincoln No. 1 mine.

Section	A		B		C		D		E	
Laboratory No	12180		12181		12182		12183		12184	
Roof, hard shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	9	0	10	0	10	0	11	0	10
Dull-coal binder	0	1	0	1½	0	2	0	2	0	2
Coal, soft and bright	2	6	2	5½	2	4	2	5	2	5
Floor, soft shale.										
Thickness of bed	3	4	3	5	3	4	3	6	3	5
Thickness of coal sampled	3	4	3	5	3	4	3	6	3	5

Section A (sample 12180) was measured at the face of the new main heading.

Section B (sample 12181) was measured at the face of right entry 2

Section C (sample 12182) was measured at the face of right entry 4.

Section D (sample 12183) was measured at the face of left entry 7.

Section E (sample 12184) was measured at the face of left entry 9.

Notes.—The coal is mined by the room-and-pillar double-entry system. At the time of sampling the coal was undercut with electric chain-cutting machines and broken down with FFFF black powder. All of the coal was shipped as run-of-mine. The daily output was about 500 tons, practically all of which was from advance workings. The tipple is about 300 feet from the mouth of the mine. There were trackage facilities for handling about 40 cars.

NANTY GLO. SPRINGFIELD NO. 1 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12128, 12129, 12130, 12131, 12132, and 12133 (pp. 78, 79).

Mine.—Springfield No. 1, a slope mine in the central Pennsylvania district, half a mile southeast of Nanty Glo on the Black Lick branch of the Cresson division of the Pennsylvania Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet 7 inches. Roof, firm shale, overlain by a sandstone cap rock 22 feet thick. Floor, a soft shale, generally smooth. Material from the roof or floor did not become mixed with the coal in mining. There are small soft "sulphur" lenses throughout the coal bed.

The bed was measured and sampled at five points in the mine by A. J. Hazlewood on April 29, 1911, as described below:

Sections of coal bed in Springfield No. 1 mine.

Section	A		B		C		D		E	
Laboratory No	12128		12129		12130		12131		12133	
Roof, sandrock, soft shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, soft, with irregular cleavage	0	11	0	11	1	0	1	0	0	10
Coal, dull	0	1	0	1	0	1½	0	1½	0	¾
Coal, very soft with a number of soft "sulphur" lenses	2	4	2	8	2	5½	2	6½	2	10¼
Floor, soft shale.										
Thickness of bed	3	4	3	8	3	7	3	8	3	9
Thickness of coal sampled	3	4	3	8	3	7	3	8	3	9

Section A (sample 12128) was measured at the face of left entry 4, 2,700 feet from the mine mouth.

Section B (sample 12129) was measured at the face of the main entry, 3,500 feet from the mine mouth.

Section C (sample 12130) was measured at the face of the third crosscut off the dip heading, 2,500 feet from the mine mouth.

Section D (sample 12131) was measured at the face of left entry 1, 3,000 feet from the mine mouth.

Section E (sample 12133) was measured on the pillar in room 3, off left entry 2.

A composite sample was made by combining face samples 12128 to 12131, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 12132.

Notes.—The mine is on a syncline, and is entered by a steep slope 430 feet long. The bed is slightly rolling; there were three or four "swamps" on the main entry. The dip entry turns to the right and at the time of sampling had considerable water in it. The high parts of the mine were dry.

The coal was undercut in the bottom part of the bed with compressed air punchers and broken down with FFFF black powder. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track with a capacity of 20 empty and 20 loaded cars. The mine had a capacity of 550 tons with an average daily output of 500 tons, which was all from advance workings. There was approximately 2,000 acres of unmined coal tributary to this opening.

PORTAGE. FORGE SLOPE NO. 1 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12369, W20396, W20397, W20398, W20399, W20400, and W20401 (p. 79).

Mine.—Forge Slope No. 1, a slope mine in the central Pennsylvania district, 2 miles north of Portage, on the Martins branch of the Pennsylvania Railroad.

Coal bed.—C′ or Upper Kittanning, Carboniferous age, Allegheny formation. Average thickness, 3 feet 5 inches. The roof is bony coal of poor quality 1 foot 6 inches to 3 feet 4 inches thick, and is overlain by shale and sandstone. Floor, fire clay underlain by limestone.

The bed was measured and sampled at six points in the mine by P. M. Riefkin on June 8, 1911, as described below:

Sections of coal bed in Forge Slope No. 1 mine.

Section	A		B		C		D		E		F	
Laboratory No.	W20396		W20397		W20398		W20399		W20400		W20401	
Roof, shale and bony coal.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, soft	..	..	..	..	..	..	0	5½	0	8	..	..
"Sulphur"	..	..	..	..	..	..	0	¼	0	¼	..	..
Coal	1	3½	1	2½	1	4	0	7	0	6	1	2¼
"Sulphur"	..	..	..	..	..	..	0	⅛	..	..	..	..
Coal	..	..	..	..	..	..	0	3	..	..	..	..
Coal, hard	0	3	0	2½	0	2	0	1½	0	2½	0	2½
Coal	1	10¼	2	0	1	11½	2	2	2	1	2	2¼
Floor, fire clay.												
Thickness of bed	3	4¾	3	5	3	5½	3	7⅜	3	5¾	3	7
Thickness of coal sampled	3	4¾	3	5	3	5½	3	7⅜	3	5¾	3	7

Section A (sample W20396) was measured near the face of the main south heading, 1 mile south of the mine mouth.

Section B (sample W20397) was measured on the rib near the face of left entry 7, off the main south entry, 1 mile west of the mine mouth.

Section C (sample W20398) was measured on the rib near the face of right entry 2, off left entry 7, off the main south entry, 4,500 feet northwest from the mine mouth.

Section D (sample W20399) was measured on the rib near the face of right entry 1, off left entry 7, off the main south heading, 5,000 feet southwest of the mine mouth.

Section E (sample W20400) was measured at the face of the main north heading, 3,000 feet north from the mine mouth.

Section F (sample W20401) was measured on the rib near the face of right entry 3, off the main north entry, 2,600 feet north from the mine mouth.

A composite sample was made by combining face samples W20396 to W20401, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 12369.

Notes.—At the time of sampling the coal was undercut with puncher machines and shot down with FFFF black powder. There were two loading tracks with a capacity of 45 empty and 45 loaded cars. There were no screens at the tipple, all of the coal being loaded as run-of-mine. Pickers were employed on the cars in loading. The mine had a capacity of 800 tons and a daily average output of 700 tons, the larger part of which was from advanced workings. The intent was to increase the output to 800 tons a day. There was approximately 300 acres of unmined coal tributary to this opening.

PORTAGE. MILLER NO. 1 SHAFT.

Sample.—Semibituminous coal; Windber field; analyses Nos. 11355, 11356, 11357, 11358, 11359, and 11360 (p. 79).

Mine.—Miller No. 1 shaft; central Pennsylvania district; a shaft mine 1 mile southeast of Portage, on the main line of the Western Pennsylvania Division of the Pennsylvania Railroad. There are railroad connections from the mine to the main line.

Coal bed.—Lower Kittanning, Miller, or B. Carboniferous age, Allegheny formation. Average thickness, about 3 feet 6 inches. Dip, 5 to 15 per cent, west. Roof, hard black shale about 18 inches thick, above which is a sandstone cap rock; floor, medium-hard smooth clay. Cover at points of sampling, 200 to 425 feet. The bed was measured and sampled at five points in the mine by Charles Enzian on December 7, 1910, as described below:

Sections of coal bed in Miller No. 1 shaft.

Section	A		B		C		D		E	
Laboratory No	11355		11356		11357		11358		11359	
Roof, hard shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Bone	[a]0	4½	[a]0	3½	[a]0	2½	[a]0	5½	[a]0	5½
Coal	2	9½	1	3¼	1	2	1	1	1	0
"Sulphur" band	..	..	0	¼	..	..	..	..	..	..
Shale, hard	..	..	..	..	0	¼	0	⅛	0	¼
Coal	..	..	1	4½	1	8½	2	3¾	2	¼
Mother coal	..	..	0	¼	0	¼	..	..	..	..
Coal	..	..	0	11½	0	3¾	..	..	..	..
Floor, soft shale.										
Thickness of bed	3	2	3	11¼	3	5¼	3	10⅜	3	6
Thickness of coal sampled	2	9½	3	7¾	3	2¾	3	4⅞	3	½

[a] Not included in sample.

Section A (sample 11355) was measured at the face of the second right dip, 2,800 feet southwest of the shaft.

Section B (sample 11356) was measured at the face of third left heading, 4,100 feet southeast of the shaft.

Section C (sample 11357) was measured on the pillar of the A-1 heading, 2,000 feet from the foot of the shaft.

Section D (sample 11358) was measured at the face of the first right dip, 1,500 feet from the foot of the shaft.

Section E (sample 11359) was measured at the face of first left heading, 3,000 feet from the foot of the shaft.

A composite sample was made by combining face samples 11355 to 11359, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 11360.

Notes.—The mine is opened by a shaft about 425 feet deep. The plan of working is triple entry, room-and-pillar. At the time of sampling the coal was undercut by hand. Black powder was used for breaking down the coal and dynamite for brushing the roof. The tipple was steel. There were two loading tracks with a capacity of 80 cars. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. The mine was comparatively new and had an average daily output of 700 tons, all of which was from advance workings. The intent was to increase the output to about 1,500 tons a day. When the pillars were pulled, the total recovery was about 90 per cent.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 160, 712, 713.

PORTAGE. PLYMOUTH NO. 1 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 11705, W17110, W17111, and W17112 (p. 80).

Mine.—Plymouth No. 1, a drift mine in the central Pensylvania district, 2¼ miles east of Portage, on the Pennsylvania Railroad.

Coal bed.—C′ or Upper Kittanning. Carboniferous age, Allegheny formation. Average thickness, 3 feet 8 inches. Roof, bony coal, overlain by shale. Floor, hard, smooth fire clay which softens readily when in contact with the air.

The bed was measured and sampled at three points in the mine by G. S. Pope on January 27, 1911, as described below:

Sections of coal bed in Plymouth No. 1 mine.

Section	A		B		C	
Laboratory No.	W17110		W17111		W17112	
Roof, bone and shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	3	1	3	1	1
Bone	[a] 0	½	..	..	[a] 0	1¼
Bone, soft	..	..	0	1	..	..
Coal	..	..	0	8	..	..
"Sulphur"	..	..	[a] 0	¼	..	..
Coal	2	4	1	8	1	11½
Floor, fire clay.						
Thickness of bed	3	7½	3	8¼	3	1¾
Thickness of coal sampled	3	7	3	8	3	½

[a] Not included in sample.

Section A (sample W17110) was measured at the face of No. 5 dip, 300 feet from the main heading.

Section B (sample W17111) was measured at the face of fourth left entry, 2,000 feet from the main heading.

Section C (sample W17112) was measured at the face of the main heading, 250 feet from eighth left entry.

Notes.—At the time of sampling the coal was undercut by hand and shot down with FFFF black powder. The tipple had one loading track with a capacity of 15 cars. There were no screens, the entire output being shipped as run-of-mine. Pickers were employed on the cars in loading. The mine had a capacity of 300 tons a day and an average daily output of 250 tons. Plans were under way for installing rope haulage and doubling the production of the mine. There were approximately 750 acres of unmined coal tributary to this opening.

PORTAGE. SONMAN NO. 2 SHAFT.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12205, 12217, W19688, W19689, W19690, W19691, W19692, W19693, and W19694 (p. 80).

Mine.—Sonman No. 2 shaft, in the central Pennsylvania district, 1 mile east of Portage, on the Sonman branch of the Pennsylvania Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Thickness, 3 feet 8 inches to 4 feet 6 inches, fairly uniform. Dip, 11½° N., 68° W. Roof, smooth shale; above the shale is a sandstone cap rock; floor, rough fire clay. Particles of the roof or floor did not become mixed with the coal in mining.

The bed was measured and sampled at seven points in the mine by P. M. Riefkin on May 1, 1911, as described below.

Sections of coal bed in Sonman No. 2 shaft.

Section	A	B	C	D	E	F	G
Laboratory No	W19688	W19689	W19690	W19691	W19692	W19693	W19694
Roof, sandstone and shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal, bony	[a]0 2½	[a]0 4	[a]0 6½	[a]0 8	[a]0 7	[a]0 7½	[a]0 5½
Coal	.. ..	.. ..	.. ..	1 2½	.. ..	1 5½	1 8½
Coal, bony	.. ..	.. ..	.. ..	0 ¼	.. ..	0 ¼	0 1
Coal	3 ½	2 5	3 10	2 5	2 8½	1 8	0 7
"Sulphur" and mother coal	.. ..	.. ..	.. ..	.. ..	0 ¼	0 ¼	Streak.
Coal, hard	.. ..	1 2	.. ..	.. ..	.. ..	.. ..	.. ..
Coal	.. ..	.. ..	.. ..	.. ..	0 8	0 7½	1 6
Floor, fire clay.							
Thickness of bed	3 3	3 11	4 4½	4 3¾	3 11¾	4 5	4 4
Thickness of coal sampled	3 ½	3 7	3 10	3 7¾	3 4¾	3 9½	3 10½

[a] Not included in sample.

Section A (sample W19688) was measured at the face of room 8, left heading 2 off dip off the main south heading.

Section B (sample W19689) was measured on a pillar near the face of room 23, first right off plane, 3,000 feet southeast of the shaft.

Section C (sample W19690) was measured at the face of room 13, left heading 1 off dip off the main south heading.

Section D (sample W19691) was measured at the face of "No. 32 crook" off the main north heading.

Section E (sample W19692) was measured at the face of "No. 28 crook," left heading 1 off dip off main south heading.

Section F (sample W19693) was measured at the face of room 10, first right off plane 17 off main north heading.

Section G (sample W19694) was measured at the face of right heading 3 off main dip off main north heading.

A composite sample was made by combining face samples W19689, W19691, and W19692. The results of an ultimate analysis of this sample are shown under laboratory No. 12217.

A composite sample was made by combining face samples W19688, W19690, W19693, and W19694. The results of an ultimate analysis of this sample are given under laboratory No. 12205.

Notes.—The mine is opened by a shaft 320 feet deep. At the time of sampling the coal was undercut by hand and broken down with black powder. The entire output was shipped as run-of-mine. Pickers were employed on the car in loading. There were two loading tracks with a capacity of 55 empty and 55 loaded cars. The daily output was 1,100 tons, about 75 per cent of which was from advance workings. There was approximately 1,500 acres of unmined coal tributary to this opening.

SPANGLER. PENNSYLVANIA NO. 21 AND NO. 22 MINES.

Sample.- Bituminous coal; Windber field; analyses Nos. 12126, 12127, 12140 to 12148, inclusive (p. 81).

Mine. Pennsylvania No. 21 and Pennsylvania No. 22, slope mines, 2 miles northwest of Spangler, on the Cresson division of the Pennsylvania Railroad.

Coal bed.—Lower Freeport or D, Carboniferous age, Allegheny formation. Average thickness, 3 feet 10 inches. Roof, bony coal overlain by "draw slate" 6 inches thick, which comes down with the coal. Floor, hard fire clay with rough surface. In mining care was taken that the material from the roof and floor did not become mixed with the coal.

The bed was measured and sampled at five points in No. 22 mine and at four points in No. 21 mine by H. I. Smith, on April 26 and 27, 1911, as described below:

Sections of coal bed in Pennsylvania No. 21 mine.

Section	A		B		C		D	
Laboratory No.	12144		12145		12146		12147	
Roof, bony coal, and "draw slate."	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	4½	..	..	0	4	..	..
Coal and "shale"	0	¼	*a* 0	1	0	½	..	..
Coal	1	0	0	8½	0	5	1	3
Coal and "sulphur"	..	..	*a* 0	1¼	*a* 0	2	*a* 0	¼
Coal	..	..	0	4½	0	3½	0	6
Coal	..	..	*a* 0	1	*a* 0	2¾	..	..
Bony coal	0	¼	*a* 0	1	*a* 0	1½	0	1
Coal	..	..	*a* 0	½	*a* 0	¾	..	..
Coal	1	4	1	1	1	0	0	10
Coal	*a* 0	½	*a* 0	¾	*a* 0	1	*a* 0	½
"Mining slate"	*a* 0	½	*a* 0	1¼	*a* 0	1½	*a* 0	1
Coal	*a* 0	1	*a* 0	1	*a* 0	¾	*a* 0	½
Coal	0	10	0	8	0	8	0	9
Floor, hard fire clay.								
Thickness of bed	3	9	3	5¾	3	6	3	7¼
Thickness of coal sampled	3	7	2	10	2	8¼	3	5

a Not included in sample.

Section A (sample 12144) was measured at the face of the main heading, 5,000 feet southwest of the mine mouth.

Section B (sample 12145) was measured at the face of the second main entry, 6,500 feet from the mine mouth.

Section C (sample 12146) was measured at the face of back heading 17. The point of sampling was 5,900 feet west of the mine mouth.

Section D (sample 12147) was measured at the face of right entry 4 off the second main entry, 6,300 feet east of the mine mouth.

A composite sample was made by combining face samples 12144 to 12147, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 12148.

Sections of coal bed in Pennsylvania No. 22 mine.

Section	A		B		C		D		E	
Laboratory No.	12126		12127		12140		12141		12142	
Roof, cannel coal and "draw slate."	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	8	1	5¾	0	11	0	10	0	4½
Mother coal and "sulphur"	*a* 0	½	..	..	0	¼	*a* 0	¼	0	½
Coal	1	3½	..	..	0	6½	..	..	0	7½
Mother coal and "sulphur"	..	..	..	..	..	..	..	..	*a* 0	¼
Coal	..	..	..	..	..	..	..	..	0	3
Coal gray, bony	0	½	*a* 0	1½	0	1½	..	..	*a* 0	1½
Coal	0	9	1	1	1	2½	1	7½	1	0
Coal	*a* 0	1	*a* 0	½	*a* 0	½	*a* 0	1	..	..
"Mining slate"	*a* 0	1	*a* 0	¾	*a* 0	1	*a* 0	1½	*a* 0	¼
Coal	*a* 0	1½	*a* 0	1	*a* 0	½	*a* 0	1	..	..
Coal	1	0	1	½	1	0	0	8½	0	10
Floor, hard fire clay.										
Thickness of bed	4	1	3	11	3	11¾	3	5¾	3	3
Thickness of coal sampled	3	9	3	7¼	3	9¾	3	2	3	1½

a Not included in sample.

Section A (sample 12126) was measured at the face of the main ninth entry, 7,200 feet southwest of the mine mouth.

Section B (sample 12127) was measured on the rib of room 9, right entry 4, off the main ninth entry, 6,200 feet southwest of the mine mouth.

Section C (sample 12140) was measured at the face of room 17, off right entry 6, off the main ninth entry, 7,400 feet from the mine mouth.

Section D (sample 12141) was measured at the face of the main back heading, 7,100 feet from the mine mouth.

Section E (sample 12142) was measured at the face of the fourteenth right off the main heading, 7,200 feet from the mine mouth.

A composite sample was made by combining face samples 12126, 12127, 12140, 12141, and 12142. The results of an ultimate analysis of this sample are given under laboratary No. 12143.

Notes.—At the time of sampling the coal was undercut both by hand and with electric chain machines and shot down with FFFF black powder and "40 per cent" nitroglycerin dynamite. There was one loading track at the tipple with a capacity of 50 empty and 100 loaded cars. All of the coal was shipped as run-of-mine. The tipple was equipped with bar screens with 3-inch openings; if screened about 50 per cent of the coal would pass through the 3-inch spaces. Pickers were employed on the cars in loading. The capacity of the storage bin was 165 tons. The mines had a capacity of 1,500 tons a day, with a daily average output of 1,000 tons, 60 per cent of which was from advance workings. There was approximately 5,000 acres of unmined coal tributary to this opening.

TWIN ROCKS. BIG BEND NO. 1 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. W19668, W19669, W19672, W19674, W19676, 12208, and 12215 (p. 82).

Mine.—Big Bend No. 1, a drift mine in Black Lick Township at Twin Rocks, on the Cresson division of the Pennsylvania Railroad.

Coal bed.—Miller, B, or Lower Kittanning. Carboniferous age, Allegheny formation. Average thickness, 3 feet 8 inches. Roof, smooth, hard, gray shale 15 feet thick, overlain with sandstone. Floor, hard, smooth shale, underlain with fire clay.

The bed was measured and sampled at five points in the mine by E. W. Miller on April 29, 1911, as described below:

Sections of coal bed in Big Bend No. 1 mine.

Section	A		B		C		D		E	
Laboratory No.	W19668		W19669		W19672		W19674		W19676	
Roof, sandstone and shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	3	7½	1	11	1	9	0	3½	4	3
"Sulphur"	..	..	0	½	..	..	..	..	..	..
"Coal"	..	..	0	5	..	..	..	..	..	..
"Sulphur" and shale	..	..	0	⅛	[a]0	¾	[a]0	⅛	..	..
Coal	..	..	1	2¼	1	9½	3	3½	..	..
Floor, shale and fire clay.										
Thickness of bed	3	7½	3	6⅞	3	7¼	3	7⅛	4	3
Thickness of coal sampled	3	7½	3	6⅞	3	6½	3	7	4	3

[a] Not included in sample.

Section A (sample W19668) was measured at the face of room 11 off the drainage heading, 2,600 feet northeast of the main opening.

Section B (sample W19669) was measured at the face of the water-level heading 2,000 feet northeast of the main opening.

Section C (sample W19672) was measured on the pillar opposite room 16, Claghorn section, 3,000 feet east of the main opening.

Section D (sample W19674) was measured on the pillar to left of main heading, 2,500 feet east of the main opening.

Section E (sample W19676) was measured on the pillar to the left of the main heading, opposite right headings 6 and 7, 2,000 feet east of the main opening.

A composite sample was made by combining face samples W19668 and W19669. The results of an ultimate analysis of this sample are shown under laboratory No. 12215.

A composite sample was made by combining face samples W19672, W19674, and W19676. The results of an ultimate analysis of this sample are shown under laboratory No. 12208.

Notes.—At the time of sampling, the coal was undercut by hand and broken down with black powder. There was no screen, the entire output being shipped as run of-mine. Pickers were employed on the cars in loading. There was one loading track with a capacity of 10 cars. The mine had a daily capacity of 450 tons, with an average output of 375 tons a day, 70 per cent of which was from advance workings.

TWIN ROCKS. BIG BEND NO. 6 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. W19670, W19671, W19673, W19675, W19677, 12707, and 12227 (p. 83).

Mine.—Big Bend No. 6, a drift mine in Black Lick Township, 1 mile north of Twin Rocks, on the Cresson division of the Pennsylvania Railroad.

Coal bed.—Miller, B, or Lower Kittanning. Carboniferous age, Allegheny formation. Average thickness, 5 feet 9 inches. The roof, a hard, smooth gray shale, 15 feet thick, is overlain by a sandstone cap rock 25 feet thick. The floor is a hard, smooth shale; below the shale is a fire clay.

The bed was measured and sampled at five points in the mine by E. W. Miller on April 29, 1911, as described below:

Sections of coal bed in Big Bend No. 6 mine.

Section	A		B		C		D		E	
Laboratory No.	W19670		W19671		W19673		W19675		W19677	
Roof, shale and sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	1½	0	3¼	2	1¼	..	..	0	¾
"Sulphur" streak	[a]0	¼	[a]0	⅜	[a]0	1½	..	..	..	..
Shale	..	..	..	..	..	..	..	..	[a]0	¼
Coal	3	7¾	3	4¼	1	7	3	9½	3	7½
Floor, shale and fire clay.										
Thickness of bed	3	9½	3	7⅞	3	9¾	3	9½	3	8½
Thickness of coal sampled	3	9¼	3	7½	3	8¼	3	9½	3	8¼

[a] Not included in sample.

Section A (sample W19670) was measured at the face of room 1, left side of right heading 1 off No. 9 drift, 900 feet south of No. 9 opening. There were sulphur streaks in the coal represented by this section.

Section B (sample W19671) was measured on the pillar between rooms 23 and 24 off the main heading, 1,500 feet northeast of the main opening. There were irregular sulphur streaks in the coal represented by this section.

Section C (sample W19673) was measured at the face of heading 13, 325 feet from the outcrop and 3,500 feet southeast of the main opening. There were sulphur streaks throughout the coal represented by this section.

Section D (sample W19675) was measured on the pillar between rooms 27 and 28 off the main heading, 2,000 feet northeast of the main opening. There were small irregular sulphur streaks in the coal represented by this section.

Section E (sample W19677) was measured at the face of room 10 on the left side of No. 9 drift, 700 feet southwest of No. 9 opening. Sulphur balls and streaks were frequent in the coal represented by this section.

A composite sample was made by combining face samples W19671 and W19675. The results of an ultimate analysis of this sample are shown under laboratory No. 12207.

Notes.—At the time of sampling the coal was undercut by hand and shot down with black powder. There was one loading track at the tipple with a capacity of 16 cars. There were no screens, the entire output being loaded as run-of-mine. Pickers were employed on the cars in loading. The mine had a daily capacity of 450 tons and an average daily output of 375 tons, of which about 70 per cent was from advance workings.

TWIN ROCKS. COMMERCIAL NO. 3 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12377, W20477, W20478, W20479, W20480, and W20481 (p. 83).

Mine.—Commercial No. 3, a slope mine at Twin Rocks, on the Cresson division of the Pennsylvania Railroad.

Coal bed.—Miller or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet 9 inches. The roof, a black shale 5 to 8 feet thick, is overlain by sandstone. The floor is shale and bottom coal, underlain by fire clay.

The bed was measured and sampled at five points in the mine by E. W. Miller on June 10, 1911, as described below:

Sections of coal bed in Commercial No. 3 mine.

Section	A		B		C		D		E	
Laboratory No.	W20477		W20478		W20479		W20480		W20481	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, sandstone and shale.										
Coal	0	5¾	0	1	0	5½	0	1	0	7⅜
"Sulphur" streak	..	..	0	⅛	0	⅛	0	½	0	⅛
"Sulphur" ball	[a] 1	2	..	..	..	..	..	..	..	..
Coal	3	4½	1	9¾	2	0	2	1¼	3	¼
"Sulphur"	..	..	[a] 0	⅜	[a] 0	⅜	0	⅛	..	..
Coal	..	..	1	6¾	0	5¼	0	4½	..	..
"Sulphur"	..	..	..	..	[a] 0	⅜	0	½	..	..
Coal	..	..	..	..	0	5¼	..	..	..	..
"Sulphur"	..	..	..	..	0	⅛	..	..	..	..
Coal	..	..	..	..	0	1¾	1	4	..	..
Floor, shale, bottom coal, and fire clay.										
Thickness of bed	5	¼	3	6	3	6¾	3	11⅞	3	8¾
Thickness of coal sampled	3	10¼	3	5⅝	3	6	3	11⅞	3	8¾

[a] Not included in sample.

Section A (sample W20477) was measured at the face of the main heading, 6,200 feet northwest of the mine mouth.

Section B (sample W20478) was measured on the pillar of fourth right heading, 5,000 feet from the main entry and 4,500 feet northeast of the mine mouth.

Section C (sample W20479) was measured at the face of seventh right heading, 450 feet from the main entry and 5,600 feet northwest of the mine mouth.

Section D (sample W20480) was measured at the face of seventh left entry, 700 feet from the main entry and 5,300 feet northwest of the mine mouth.

Section E (sample W20481) was measured at the face of fifth right heading, 5,000 feet from the main entry and 4,200 feet north of the mine mouth.

A composite sample was made by combining face samples W20477, W20479, W20480, and W20481). The results of an ultimate analysis of this sample are given under laboratory No. 12377.

Notes.—At the time of sampling the coal was undercut by hand and with machines and shot down with FFF black powder. There was one leading track at the tipple which had a capacity of 28 empty and 28 loaded cars. There were no screens, the entire output being shipped as run-of-mine. Pickers were employed on the cars in loading. The mine was equipped to produce about 1,000 tons a day and was operating at full capacity. There was approximately 850 acres of unmined coal tributary to this opening.

TWIN ROCKS. COMMERCIAL NO. 4 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12364, W17061, W20501, W20503, W20505, W20506, W20508 (p. 83).

Mine.—Commercial No. 4, a slope mine near Twin Rocks, on the Cresson division of the Pennsylvania Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet 9 inches. Roof, a black shale 5 to 8 feet thick, above which is a sandstone cap rock. Floor, shale, underlain by fire clay.

The bed was measured and sampled at five points in the mine by P. M. Riefkin on June 12, 1911 and at one point by G. S. Pope on January 26, 1911, as described below:

Sections of coal bed in Commercial No. 4 mine.

Section	A		B		C		D		E		F	
Laboratory No.	W20501		W20503		W20505		W20506		W20508		W17061	
Roof, sandstone and shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	4	2	1	2	0	2	0	1	11½	0	6
"Sulphur"	0	¾	0	¼	0	½	0	⅛	[a]0	½	0	¼
Coal	..	..	..	..	0	3¼	..	..	..	..	..	..
"Sulphur"	..	..	..	..	0	⅛	..	..	..	..	..	..
Coal	..	..	..	..	0	2¼	..	..	..	..	..	..
Mother coal	..	..	..	..	0	¼	..	..	..	..	..	..
Coal	1	3¼	1	3½	1	2	1	10½	1	7½	3	1¼
Floor, shale and fire clay.												
Thickness of bed	3	8	3	4¾	3	8⅜	3	10⅝	3	7½	3	7½
Thickness of coal sampled	3	8	3	4¾	3	8⅜	3	10⅝	3	7	3	7½

[a] Not included in sample.

Section A (sample W20501) was measured 100 feet from the face of the main heading, 5,200 feet north of the mine mouth.

Section B (sample W20503) was measured on the sixth pillar of east entry 9 off right entry 2 off the main entry, 3,800 feet northeast of the mine mouth.

Section C (sample W20505) was measured at the face of east entry 6 off right entry 3 off the main entry, 4,000 feet northeast of the mine mouth.

Section D (sample W20506) was measured on the rib near the face of east entry 7 off right entry 3 off the main entry, 4,800 feet northeast of the mine mouth.

Section E (sample W20508) was measured at the face of right entry 3 off the main entry, 4,900 feet northeast of the mine mouth.

Section F (sample W17061) was measured at the face of the third main entry off No. 4 slope.

A composite sample was made by combining face samples W20501, W20505, W20506, and W20508. The results of an ultimate analysis of this sample are shown under laboratory No. 12364.

Notes.—At the time of sampling the coal was undercut both by hand and with machines and broken down with FFF black powder. There were no screens, the entire output being shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track with a capacity of 26 empty and 26 loaded cars. The capacity of the mine was 600 tons a day with an average daily output of 450 tons. There were approximately 850 acres of unmined coal.

TWIN ROCKS. COMMERCIAL NO. 5 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12375, W17062, W20499, W20500, W20502, W20504, and W20507 (p. 84).

Mine.—Commercial No. 5, a slope mine 1 mile from Twin Rocks, on the Cresson division of the Pennsylvania Railroad.

Coal bed.—Miller or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet 10 inches. Roof, shale 3 to 15 feet thick, overlain by a sandstone cap rock; floor, shale underlain with fire clay.

The bed was measured and sampled at five points in the mine by E. W. Miller on June 12, 1911, and at one point in the mine by P. M. Riefkin on January 26, 1911, as described below:

Sections of coal bed in Commercial No. 5 mine.

Section	A		B		C		D		E		F	
Laboratory No.	W17062		W20499		W20500		W20502		W20504		W20507	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, sandstone and shale.												
Coal	0	10	0	11¼	0	4½	1	11	0	1½	1	2
"Sulphur"	[a]0	½	0	¼	[a]0	½	[a]0	½	[a]0	¼	..	..
Coal	..	..	1	¼	0	5½	..	..	0	2½	..	..
"Sulphur"	..	..	0	¼	0	¼	..	..	[a]0	¼	0	¼
Coal	..	..	0	5½	1	5	..	..	1	1½	1	2¼
"Sulphur"	..	..	0	¼	[a]0	¾	..	..	0	½	..	..
Coal	..	..	0	1½	1	2	..	..	0	7½	..	..
"Sulphur"	..	..	0	¼	[a]0	1	..	..	[a]0	¼	0	¼
Coal	2	9½	1	0	..	..	1	9	1	5½	1	3½
Floor, shale and fire clay.												
Thickness of bed	3	8	3	7½	3	7½	3	8½	3	7¼	3	8¼
Thickness of coal sampled	3	7½	3	7½	3	5¼	3	8	3	6½	3	8¼

[a] Not included in sample.

Section A (sample W17062) was measured at the face of room 1 off east heading 10 off the main entry.

Section B (sample W20499) was measured at the face of the main heading; 4,700 feet northeast of the mine mouth.

Section C (sample W20500) was measured at the face of room 7 off right heading 1; 500 feet from the second parallel entry and 3,400 feet northeast of the mine mouth.

Section D (sample W20502) was measured at the face of east heading 12; 325 feet from the main entry and 4,700 feet northeast of the mine mouth.

Section E (sample W20504) was measured at the face of east heading 11; 800 feet from the main entry and 4,000 feet northeast of the mine mouth.

Section F (sample W20507) was measured at the face of room 10 off east heading 10; 750 feet from the main heading and 3,900 feet northeast of the mine mouth.

A composite sample was made by combining face samples W20499, W20500, W20502, W20504, and W20507. The results of an ultimate analyses of this sample are shown under laboratory No. 12375.

Notes.—At the time of sampling the coal was undercut by hand and shot down with FFF black powder. There were no screens, the entire output being shipped as run-of-mine coal. Pickers were employed on the cars in loading. There was one loading track at the tipple with a capacity of 28 empty and 28 loaded cars. The mine was equipped to produce 500 tons a day and had an average daily output of 300 tons. An increase to 800 tons was contemplated.

CENTER COUNTY.

OSCEOLA MILLS. ELECTRIC MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12067, 12068, 12069, 12070, and 12190 (p. 84).

Mine.—Electric, a drift mine, one-half mile south of Osceola Mills on the Pennsylvania Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, 5 feet. Roof, smooth shale; above the shale is a cap rock about 15 feet thick. Floor, smooth hard fire clay.

The bed was measured and sampled at four points in the mine by P. M. Riefkin on April 18, 1911, as described on the following page.

Sections of coal bed in Electric mine.

Section	A	B	C	D
Laboratory No	12067	12068	12069	12070
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Top coal	[a]0 1½	[a]0 1	[a]0 1	[a]0 1
Coal	0 9¼	0 9	0 8¼	0 6
Sulphur, soft	.. ..	0 ¼	0 ¼	0 ¼
Coal	.. ..	0 4½	0 4	0 4½
Coal, hard	[a]0 3	[a]0 2	[a]0 2½	[a]0 4
Coal, bony	[a]0 4	[a]0 3	[a]0 4	[a]0 3½
Coal	1 11½	1 9	1 8	1 7½
"Sulphur" streaks, soft	.. ..	0 ¼	.. ..	.. ..
Coal	.. ..	0 2¾	.. ..	.. ..
"Sulphur"	0 ¼	[a]0 ½	[a]0 1	[a]0 ½
Coal	.. ..	0 5	.. ..	.. ..
"Sulphur"	.. ..	[a]0 ¾	.. ..	.. ..
Coal	1 0	0 7	1 2¾	1 3
Bottom coal	[a]0 4½	[a]0 5½	[a]0 3	[a]0 4
Floor, hard fire clay.				
Thickness of bed	4 10	5 2½	4 10¾	4 10¼
Thickness of coal sampled	3 9	4 1¾	3 11¼	3 9¼

[a] Not included in sample.

Section A (sample 12067) was measured at the face of right entry 1, off the new drift entry.

Section B (sample 12068) was measured on the pillar at room 9, off left entry 5, off the main entry.

Section C (sample 12069) was measured on the pillar at room 7, off right entry 4, off the main heading.

Section D (sample 12070) was measured on the pillar at room 5, off left entry 5, off the main heading.

A composite sample was made by combining face samples 12068, 12069, and 12070. The results of an ultimate analysis of this sample are shown under laboratory No. 12190.

Notes.—At the time of sampling the coal was undercut and then broken down with FFFF black powder. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track with a capacity of 20 empty and 15 loaded cars. The mine had a capacity of 400 tons a day; the average output was about 300 tons, 80 per cent of which was from pillars and 20 per cent from advance workings. There were approximately 200 acres of pillars to be taken out through this opening.

OSCEOLA MILLS. MOSHANNON NO. 10 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12057, 12058, 12059, 12060, 12061, and 12062 (p. 85).

Mine.—Moshannon No. 10, a drift mine in the Clearfield district one-fourth of a mile north of Osceola Mills on the Pennsylvania Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Thickness, 3½ to 6 feet, average, 5 feet. Roof, smooth shale; floor, hard fire clay.

The bed was measured and sampled at five points in the mine by P. M. Riefkin on April 18, 1911, as described below:

Sections of coal bed in Moshannon No. 10 mine.

Section	A	B	C	D	E
Laboratory No	12057	12058	12059	12060	12061
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Top coal	0 1	[a]0 ½	.. ..	.. ..	[a]0 2
Coal	0 6	0 6½	0 8¾	0 7	0 3¼
Coal, hard (gray)	[a]0 4	[a]0 4	[a]0 2½	[a]0 2½	[a]0 3½
Coal, bony	[a]0 6	[a]0 3½	[a]0 4½	[a]0 3	[a]0 4½
Coal	1 5	2 ½	1 9	1 8	1 6½
"Sulphur"	[a]0 ¼	[a]0 ½	0 ¼	[a]0 ¼	.. ..
Coal	0 11	0 10½	0 5	1 0	.. ..
"Sulphur"	[a]0 1	.. ..	[a]0 ½	.. ..	[a]0 ½
Coal	0 6½	.. ..	0 4¾	.. ..	0 4½
Bottom coal	0 2	0 3	0 4½	.. ..	0 4½
Floor, fire clay.					
Thickness of bed	4 6¾	4 5	4 3¾	3 8¾	3 5¼
Thickness of coal sampled	3 7½	3 8½	3 8¼	3 3	2 6¾

[a] Not included in sample.

Section A (sample 12057) was measured on the rib of room 18, 40 feet from left entry 2, off right entry 4.

Section B (sample 12058) was measured at the face of room 21, off the left main heading.

Section C (sample 12059) was measured at the face of room 16, off the right main heading, near the first crosscut to the right.

Section D (sample 12060) was measured at the face of right heading 1.

Section E (sample 12061) was measured at the face of room 16, off right heading 2.

A composite sample was made by combining face samples 12057 to 12061. The results of an ultimate analysis of this sample are given under laboratory No. 12062.

Notes.—At the time of sampling the coal was undercut by electric cutting machines and shot down with FFFF black powder. About 90 per cent of the output was shipped as run-of-mine coal, the machine cuttings, which amounted to about 10 per cent of the output, being loaded separately. Pickers were employed on the cars in loading. There was one loading track with a capacity of 25 empty and 15 loaded railroad cars. The mine was equipped to produce 700 tons a day and had an average daily output of 500 tons, about 75 per cent of which was from advance workings. An increase of about 50 per cent in the output was contemplated. There was approximately 600 acres of unmined coal tributary to this opening.

OSCEOLA MILLS. WESTON MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12063, 12064, and 12065 (p. 85).

Mine.—Weston, a drift mine in the Clearfield district, one-half mile south of Osceola Mills, on the Pennsylvania Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, 5 feet. Roof, smooth black shale; floor, hard smooth fire clay. Neither roof nor floor material got mixed with the coal in mining.

The bed was measured and sampled at three points in the mine by P. M. Riefkin on April 18, 1911, as described below:

Sections of coal bed in Weston mine.

Section	A		B		C	
Laboratory No.	12063		12064		12065	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Top coal			[a]0	1	[a]0	1
Coal	0	9½	1	2	1	4
"Sulphur"	[a]0	¼	..	..	..	..
Coal	0	4½	..	..	..	..
Coal, bony (gray)	[a]0	2	[a]0	1	[a]0	1
Coal, bony	[a]0	4	[a]0	4	[a]0	4
Coal, gray	[a]0	1½			..	..
Coal	2	5½	2	11	3	3
"Sulphur"	..	..	[a]0	½	..	..
Coal	..	..	0	3	..	..
Bottom coal	[a]0	2½	[a]0	3	[a]0	2
Floor, hard fire clay.						
Thickness of bed	4	5¾	5	1½	5	3
Thickness of coal sampled	3	7½	4	4	4	7

[a] Not included in sample.

Section A (sample 12063) was measured at the face of left entry 4, off the main entry.

Section B (sample 12064) was measured on the rib of the main heading at left entry 7.

Section C (sample 12065) was measured on a pillar at room 8, off right entry 1, off the main heading.

A composite sample was made by combining face samples 12063 and 12064. The results of an ultimate analysis of this sample are shown under laboratory No. 12066.

Notes.—At the time of sampling the coal was undercut by hand and broken down with FFFF black powder. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track with a capacity of 20 empty and 15 loaded cars. The mine had a capacity of 400 tons and a daily average output of 200 tons. Approximately 400 acres of unmined coal was to be developed from a new opening on this property.

CLEARFIELD COUNTY.

BOARDMAN. POTTS RUN NO. 3 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12093, 12094, 12095, 12096, 12097, and 12098 (pp. 85, 86).

Mine.—Potts Run No. 3, a drift mine in the Clearfield district, 1 mile west of Boardman, on the New York Central Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet 10 inches. Roof, shale; floor, fire clay.

The bed was measured and sampled at five points in the mine by P. M. Riefkin on April 24, 1911, as described below:

Sections of coal bed in Potts Run No. 3 mine.

Section	A		B		C		D		E	
Laboratory No	12093		12094		12095		12096		12097	
Roof, draw shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in*	*Ft.*	*in.*
Coal	..	..	..	..	..	..	[a]0	1½	0	3½
Sulphur	..	..	..	..	..	..	..	..	Streak.	
Coal	2	3	2	2¼	2	2	2	3	1	11
Bony coal to shale	[a]0	1	[a]0	⅜	[a]0	½	[a]0	1	[a]0	1½
Coal, gray	0	2½	..	..	..	..	..	..	..	..
Coal	1	1	1	5	1	4	1	6	1	3¼
Floor, fire clay.										
Thickness of bed	3	7½	3	7⅝	3	6½	3	11½	3	7¼
Thickness of coal sampled	3	6½	3	7¼	3	6	3	9	3	5¾

[a] Not included in sample.

Section A (sample 12093) was measured at the face of right entry 3, off the main entry, 1,400 feet southwest of the mine mouth.

Section B (sample 12094) was measured 10 feet from the face on the rib of right entry 4, off the main entry, 1,700 feet southwest of the mine mouth.

Section C (sample 12095) was measured at the face of left entry 3, off the main entry, 1,680 feet northeast of the mine mouth.

Section D (sample 12096) was measured at the face of the main heading, 2,000 feet north of the mine mouth.

Section E (sample 12097) was measured at the face of room 12, off right entry 2, off the main entry.

A composite sample was made by combining face samples 12093 to 12097, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 12098.

Notes.—At the time of sampling the coal was undercut by hand and broken down with FFFF black powder. Dynamite was used for brushing the roof and floor. There was one loading track with a capacity of 18 empty and 15 loaded cars. Pickers were employed on the car in loading. The mine had a capacity of 550 tons a day.

BRISBIN. LENORE NO. 1 AND NO. 2 MINES.

Sample.—Bituminous coal; Windber field; analyses Nos. 12044, 12045, 12046, and 12047 (p. 86).

Mines.—Lenore No. 1 and Lenore No. 2, drift mines in the Clearfield district, 1 mile southwest of Brisbin, on the Pennsylvania Railroad.

Coal bed.—Upper Freeport or E. Carboniferous age, Allegheny formation. Average thickness of coal mined, 3 feet. Roof, smooth sandstone; above the sandstone is a second cap rock. Floor, smooth, hard, dark fire clay.

The coal bed was measured and sampled at one point in No. 1 mine and at two points in No. 2 mine by P. M. Riefkin on April 17, 1911, as described below:

Sections of coal bed in Lenore No. 1 and No. 2 mines.

Section	A		B		C	
Laboratory No.	12044		12045		12046	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	5½	..	..	..	..
Mother coal	Streak.		..	..	..	..
Coal	1	11	2	3½	2	2¾
Coal, hard	0	3	0	3½	0	4
Floor, hard, dark fire clay.						
Thickness of bed	2	7½	2	7	2	6¾
Thickness of coal sampled	2	7½	2	7	2	6¾

Section A (sample 12044) was measured at the face of left heading 3, off No. 2 drift.

Section B (sample 12045) was measured at the face of left heading 2, off No. 2 drift.

Section C (sample 12046) was measured at the face of left heading 1, off the main heading off No. 1 drift.

Notes.—At the time of sampling the coal at these mines was undercut by hand and shot down with FFFF black powder. Both mines load coal over the same tipple. There was one loading track with a capacity of 10 empty and 10 loaded cars. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. The mines were equipped to produce 200 tons a day, with an average daily output of 150 tons, all from advance workings. There was approximately 300 acres of unmined coal tributary to these entries. The two mines are equipped as a single mine.

MADERA. BUCHER MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12376, W20435, W20436, W20437, W20438, and W20439 (p. 86).

Mine.—Bucher, a drift mine in the Clearfield district, 2 miles north of Madera, on the Pennsylvania Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet 6 inches. The roof, a dark shale, is overlain by cannel coal 2 feet thick, above which is a sandstone cap rock. The floor is a hard shale 1 to 2 feet thick, underlain by a hard, rough clay about 10 feet thick.

The bed was measured and sampled at five points in the mine by H. I. Smith on June 9, 1911, as described below:

Sections of coal bed in Bucher mine.

Section	A		B		C		D		E	
Laboratory No.	W20435		W20436		W20437		W20438		W20439	
Roof, sandstone, cannel coal, and dark shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	..	..	..	..	..	..	1	½	0	8½
Bony coal	[a] 0	2	[a] 0	¼	[a] 0	1	..	..	..	..
Mother coal	..	..	..	..	..	..	..	..	0	¼
Coal	0	7	0	11	0	11	..	..	0	3½
Cannel coal	0	1	0	1	0	1	0	1	0	1
Coal	0	11½	0	10½	0	11	0	8	0	10
"Mining slate"	[a] 0	½	[a] 0	¼	Streak.		[a] 0	½	[a] 0	1½
Coal	0	2	..	..	0	4½	[a] 0	2½	0	2½
"Sulphur"	..	..	..	..	0	¼	[a] 0	¼	0	½
Coal	1	1½	1	4	0	10¼	1	6	0	11
Floor, shale and fire clay.										
Thickness of bed	3	1½	3	3	3	3	3	6¾	3	2¾
Thickness of coal sampled	2	11	3	2½	3	2	3	3½	3	1¼

[a] Not included in sample.

Section A (sample W20435) was measured at the face of ninth left entry, off first cross heading, 3,400 feet northeast of the mouth of the main entry.

Section B (sample W20436) was measured at the face of eighth right heading, 3,800 feet northeast of the mouth of the main heading.

Section C (sample W20437) was measured at the face of tenth right heading, 4,500 feet northeast of the mouth of the main entry.

Section D (sample W20438) was measured at the face of seventh left heading, 3,000 feet northeast of the mouth of the main entry.

Section E (sample W20439) was measured at the face of seventh right heading, 3,200 feet northeast of the mouth of the main entry.

A composite sample was made by combining face samples W20435 to W20439, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 12376.

Notes.—At the time of sampling the coal was undercut with machines and broken down with black powder. There were no screens, the entire output being shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track at the tipple with a capacity of about 40 cars. The mine had a capacity of 400 tons a day and an average daily output of 250 tons, of which the larger part was from advance workings. There was approximately 600 acres of unmined coal tributary to this opening.

MADERA. MORGAN RUN MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12368, W20402, W20403, W20404, W20405, and W20406 (p. 87).

Mine.—Morgan Run, a drift mine in the Clearfield district, 1 mile east of Madera on the Pennsylvania Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet 6 inches. The roof, a hard, dark, smooth shale, is overlain by 2 feet of cannel coal; above the cannel is sandstone. Floor, shale, underlain by clay.

The bed was measured and sampled at five points in the mine by H. I. Smith on June 8, 1911, as described below:

Sections of coal bed in Morgan Run mine.

Section	A	B	C	D	E
Laboratory No.	W20402	W20403	W20404	W20405	W20406
Roof, sandstone, cannel coal, and shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	1 ½	0 8½	0 2½	0 3	0 9
"Sulphur"	Streak.	Streak.	Streak.	Streak.	Streak.
Coal	0 3½	0 2	0 9	0 3½	0 4
Mother coal	0 1	.. ..	.. ..	.. ..	.. ..
Cannel coal	.. ..	0 2½	.. ..	.. ..	0 1
"Sulphur"	.. ..	.. ..	Streak.	[a] 0 ½	.. ..
Coal	0 7	0 3	.. ..	0 6	0 11
Cannel coal	.. ..	.. ..	0 1¼	0 1	0 1
"Binder slate"	[a] 0 ¾	[a] 0 ⅜	Streak.	Streak.	[a] 0 1
Coal	0 3½	0 5½	1 3	0 10	1 3½
"Binder slate"	Streak.	[a] 0 1½	Streak.	[a] 0 1	.. ..
Coal	0 2	0 4½	0 4	0 10	.. ..
"Sulphur"	Streak.	Streak.	.. ..	Streak.	.. ..
Coal	0 3	.. ..	.. ..	0 5½	.. ..
"Sulphur" ball	[a] 0 ½	.. ..	[a] 0 ½	.. ..	.. ..
Coal	0 7¾	1 0	0 10½	.. ..	.. ..
Bony coal	.. ..	.. ..	0 1	0 ¾	.. ..
Floor, shale.					
Thickness of bed	3 5½	3 3⅞	3 7¾	3 5¼	3 6½
Thickness of coal sampled	3 4¼	3 2	3 7¼	3 3¾	3 5½

[a] Not included in sample.

Section A (sample W20402) was measured at the face of south entry 4, off right entry 5.

Section B (sample W20403) was measured at the face of east entry 3, off right entry 5.

Section C (sample W20404) was measured at the face of south entry 3, off right entry 5.

Section D (sample W20405) was measured at the face of south entry 1, off right entry 5.

Section E (sample W20406) was measured at the face of the main heading.

A composite sample was made by combining face samples W20402 to W20406, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 12368.

Notes.—At the time of sampling the coal was undercut by hand and broken down with black powder. There was one loading track at the tipple with a capacity of 16 empty and 16 loaded cars. Pickers were employed on the cars in loading. The mine was equipped to produce 400 tons a day; the average daily output was 380 tons. The unmined area was approximately 500 acres.

MORRISDALE. MORRISDALE NO. 1, NO. 2, AND NO. 3 MINES.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12072 to 12082, inclusive, and 12090 and 12092 (pp. 87, 88).

Mines.—Morrisdale No. 1, Morrisdale No. 2, and Morrisdale No. 3 shaft mines, each about 130 feet deep, in the Clearfield district, 1 mile south of Morrisdale, on the New York Central & Hudson River Railroad and the Pennsylvania Railroad.

Coal beds.—Lower Kittanning or B, and the Middle Kittanning or C. Carboniferous age, Allegheny formation. The coal, as mined, has an average thickness of 4 feet 6 inches in the C bed, and about 3 feet 6 inches in the B bed. The roof of both beds is a sandy shale; the floor is a hard fire clay with smooth surface. The B bed was measured and sampled at three points in No. 1 mine and at three in No. 3 mine and the C bed at two points in No. 1 mine and at two in No. 2 mine by P. M. Riefkin on April 20 and 21, 1911, as described below:

Sections of B bed in Morrisdale mines.

Mine	Shaft No. 1.			Shaft No. 3.		
Section	A	B	C	D	E	F
Laboratory No.	12074	12075	12081	12076	12077	12078
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Top coal	[a] 0 ¼	0 ½	.. ..	[a] 0 ½	[a] 0 ½	[a] 0 1
Coal	0 4½	0 5	.. ..	0 6	0 8	0 6½
"Sulphur"	Streak.	[a] 0 ½	.. ..	.. ..	.. ..	.. ..
Coal	0 6¼	0 4½	0 10½	.. ..	.. ..	.. ..
Bone	[a] 0 ½	[a] 0 3	[a] 0 2¾	[a] 0 ½	[a] 0 6½	[a] 0 7
Bony coal	[a] 0 4	[a] 0 2½	[a] 0 3¼	[a] 0 6	[a] 0 1½	.. ..
Coal	1 1	1 6	2 0	2 2	2 3½	2 8
"Sulphur"	[a] 0 ¼	.. ..	Streak.	[a] 0 ½	.. ..	.. ..
Coal	0 9½	.. ..	.. ..	0 10	.. ..	.. ..
"Sulphur"	Streak.	0 ½	0 ¼	.. ..	.. ..	.. ..
Coal	0 10	1 5¼	0 8	.. ..	.. ..	.. ..
Floor, hard clay.						
Thickness of bed	4 ¼	4 3¾	4 1¾	4 1½	3 8	3 10½
Thickness of coal sampled	3 7¼	3 9¾	3 6¾	3 6	2 11½	3 2½

[a] Not included in sample.

Section A (sample 12074) was measured at the face of the main heading, 5,240 feet from the bottom of shaft No. 1.

Section B (sample 12075) was measured at the face of room 13, off eighth right heading off the main heading, 5,040 feet from the bottom of shaft No. 1.

Section C (sample 12081) was measured at the face of room 45, off fourth right entry, off the main heading, 5,200 feet from the bottom of shaft No. 1.

Section D (sample 12076) was measured at the face of room 5, off first left heading, off new slope tunnel, 1,400 feet from shaft No. 3.

Section E (sample 12077) was measured at the face of shaft No. 2 heading, main dip, 5,500 feet from shaft No. 3.

Section F (sample 12078) was measured at the face of the Morrisdale heading, 6,300 et from shaft No. 3.

A composite sample was made of face samples 12074, 12075, and 12081. The results of an ultimate analysis of this sample are shown under laboratory No. 12090.

A composite sample was also made of face samples 12076, 12077, and 12078. The results of an ultimate analysis of this sample are shown under laboratory No. 12092.

Sections of C bed in Morrisdale mines.

Mine	Shaft No. 2.		Shaft No. 1.	
Section	A	B	C	D
Laboratory No.	12072	12073	12079	12080
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Top, bony coal	0 1½	0 2	[a]0 3¾	Streak.
Coal	.. ..	.. ..	0 7½	0 6
Mother coal	.. ..	.. ..	.. ..	0 ⅛
Coal	.. ..	1 7½	1 7	1 4
"Sulphur"	.. ..	.. ..	0 ¼	.. ..
Coal, gray	.. ..	0 2½	.. ..	0 1
Coal	2 11½	2 0	2 5½	1 3½
Coal, gray	0 1	.. ..	.. ..	0 1
Coal	0 4¼	.. ..	.. ..	0 10
Shale	.. ..	.. ..	.. ..	[a]0 ¼
Mother coal	0 ¼	.. ..	.. ..	.. ..
Coal	0 8½	.. ..	.. ..	0 2
Bony coal	[a]0 1¼	.. ..	.. ..	0 ⅛
Coal	0 6	.. ..	.. ..	0 2
Bottom coal	.. ..	[a]0 1	.. ..	.. ..
Floor, fire clay.				
Thickness of bed	4 10¼	4 1	5 0	4 6
Thickness of coal sampled	4 9	4 0	4 8¼	4 5¾

[a] Not included in sample.

Section A (sample 12072) was measured at the face of the sixth heading, 4,500 feet from the bottom of shaft No. 2.

Section B (sample 12073) was measured at the face of room 9, off the second left heading, off Lucky strike, 2,200 feet from the bottom of shaft No. 2.

Section C (sample 12079) was measured at the face of the sump heading, 3,100 feet from shaft No. 1.

Section D (sample 12080) was measured at the face of the McKinley heading off Truck main heading, 5,850 feet from the bottom of shaft No. 1.

A composite sample was made by combining face samples 12072 and 12073. The results of an ultimate analysis of this sample are given under laboratory No. 12091.

A composite sample was also made by combining face samples 12079 and 12080. The results of an ultimate analysis of this sample are shown under laboratory No. 12082.

Notes.—At the time of sampling the coal was undercut with air punchers and shot down with black powder. There were four loading tracks at the tipple with a capacity of 120 empty and 160 loaded railroad cars. The entire production was shipped as run-of-mine; pickers were employed on the cars in loading. The mine was equipped to produce about 2,700 tons a day and had a daily output of 2,240 tons. About 75 per cent of the coal was derived from advance workings. It was planned to increase the production about 600 tons at an early date. There was approximately 4,000 acres of unmined coal tributary to these shafts. All of the mines loaded coal over the same tipple.

MUNSON. COLORADO NO. 5 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12109, 12110, 12111, 12112, 12113, and 12114 (pp. 88, 89).

Mine.—Colorado No. 5, a drift mine in the Clearfield district, at Munson, on the New York Central & Hudson River Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, 4 feet. Roof, shale; floor, fire clay. Particles of the roof or floor did not become mixed with the coal in mining.

The bed was measured and sampled at five points in the mine by H. I. Smith on April 22, 1911, as described below:

Sections of coal bed in Colorado No. 5 mine.

Section	A		B		C		D		E	
Laboratory No.	12109		12110		12111		12112		12113	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Top coal	[a]0	9	[a]0	9½	[a]0	9½	[a]0	7½	[a]0	9½
Coal, bony	[a]0	4	[a]0	3	[a]0	4	[a]0	6	[a]0	3
Coal, gray	1	0	1	2½	0	6¼	0	5½	0	8
Coal	..	..	..	..	0	1½	0	1	0	3
Coal, gray	..	..	..	..	0	3½	0	½	0	1
Coal	..	..	..	..	..	..	0	1½	..	..
Coal, gray	..	..	..	..	..	..	0	3	..	..
Coal	2	0	1	10½	2	0	2	1	1	8
"Sulphur"	Streak.		Streak.		0	½	Streak.		0	⅞
Coal	..	..	0	1	0	3	0	1½	1	¾
Floor, fire clay.										
Thickness of bed	4	1	4	2½	4	4¼	4	3½	4	10⅛
Thickness of coal sampled	3	0	3	2	3	2¾	3	2	3	9⅝

[a] Not included in sample.

Section A (sample 12109) was measured at the face of sixth left entry, off the line heading.

Section B (sample 12110) was measured at the face of eighth left entry, off the main heading, 3,000 feet from the drift mouth.

Section C (sample 12111) was measured at the face of the main heading, 3,600 feet from the drift mouth.

Section D (sample 12112) was measured at the face of the line heading.

Section E (sample 12113) was measured at the face of sixth left heading, off the main heading.

A composite sample was made by combining face samples 12109 to 12113, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 12114.

Notes.—At the time of sampling the coal was undercut by chain machines in the lower part of the bed and broken down with black powder. At the tipple were two loading tracks with a capacity of 20 empty and 15 loaded cars. The cars were shifted twice daily by the railroad company. The coal was hand picked wherever necessary. The mine had a capacity of 600 tons, with a daily output of 350 tons, derived principally from advance workings.

OSCEOLA MILLS. FAIRMOUNT NO. 2 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. W17010 and W17012 (p. 89).

Mine.—Fairmount No.2, a drift mine in the Clearfield district, 3 miles west of Osceola Mills on the Pennsylvania Railroad.

Coal bed.—Lower Freeport or D. Carboniferous age, Allegheny formation. Thickness, 5 to 6 feet. Roof, bone; floor, shale underlain by fire clay.

The bed was measured and sampled at two points in the mine by P. M. Riefkin on January 23, 1911, as described below:

Sections of coal bed in Fairmount No. 2 mine.

Section	A		B	
Laboratory No.	W17010		W17012	
Roof, bone.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	11¼	1	4¾
Mother coal	0	¾	..	..
"Sulphur"	..	..	0	¼
Coal	1	5¼	1	6
"Sulphur"	0	¼	Trace.	
Coal	0	7½	2	4¼
Floor, shale.				
Thickness of bed	5	1	5	3¼
Thickness of coal sampled	5	1	5	3¼

Section A (sample W17010) was measured at the face of room 5, off second left heading.

Section B (sample W17012) was measured at the face of room 14, off eighth right heading.

A composite sample was made by combining face samples W17010 and W17012. The results of an ultimate analysis of this sample are shown under laboratory No. 17111.

Notes.—At the time of sampling the coal was undercut by hand and shot down with black powder. There were no screens at the tipple, the entire output being shipped as run-of-mine. The average daily output was about 300 tons.

PHILIPSBURG. GUION MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12367, W20369, W20370, W20371, W20372, and W20373 (p. 89).

Mine.—Guion, a drift mine in the Clearfield district, 2 miles west of Philipsburg (Center County) on the Pennsylvania Railroad.

Coal bed.—Miller, B, or Lower Kittanning. Carboniferous age, Allegheny formation. Average thickness, 3 feet 4 inches. Roof, black shale 1 foot thick, overlain by roof coal 1 foot thick; above the roof coal is a sandstone cap rock. Floor, a hard sulphur-bearing rock 8 inches thick, underlain by soft smooth fire clay.

The bed was measured and sampled at five points in the mine by H. I. Smith on June 7, 1911, as described below:

Sections of coal bed in Guion mine.

Section	A		B		C		D		E	
Laboratory No.	W20369		W20370		W20371		W20372		W20373	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, sandstone, roof coal and black shale.										
Coal, bony	0	9	..	..	[a] 0	2½	..	..	[a] 0	2½
Coal with flakes of sulphur on "slips"	..	..	..	..	[a] 0	4½	0	3½	..	..
Coal	..	..	1	2	..	..	1	0	0	5
Coal, hard	0	8	0	2	..	..	0	5	..	..
Shale	..	..	..	..	[a] 0	¼	..	..	[a] 0	1
Coal	1	6	1	8	0	3½	1	5	0	5
"Sulphur"	..	..	..	..	[a] 0	¼	..	..	..	..
Cannel coal	0	2½	0	2	..	..	0	4	..	..
Coal, hard	..	..	..	..	0	10½	..	..	0	8
Coal, soft, fibrous	..	..	..	..	0	11	..	..	0	9
"Sulphur"	..	..	..	..	Streak.		..	..	0	¼
Coal	..	..	..	..	0	7	..	..	0	11½
Floor, sulphur-bearing rock and fire clay.										
Thickness of bed	3	1½	3	2	3	4	3	5½	3	6¼
Thickness of coal sampled	3	1½	3	2	2	8	3	5½	3	2¾

[a] Not included in sample.

Section A (sample W20369) was measured at the face of first right heading, off right entry 2, 4,000 feet from the mine mouth.

Section B (sample W20370) was measured at the face of second right heading, 4,000 feet from the mouth of the main entry.

Section C (sample W20371) was measured at the face of the back heading, off right entry 1, 2,500 feet from the mouth of the main entry.

Section D (sample W20372) was measured 50 feet from the face of first left heading, off right entry 2.

Section E (sample W20373) was measured at the face of first left heading, off right entry 1, about 2,200 feet from the mouth of the main entry.

A composite sample was made by combining face samples W20369 to W20373. The results of an ultimate analysis of this sample are shown under laboratory No. 12367.

Notes.—At the time of sampling the coal was undercut with machines and shot down with black powder. There was one loading track, with a capacity of about 25 cars. There were no screens, the entire output being shipped as run-of-mine. The mine had a capacity of 300 tons a day, and an average daily output of about 250 tons. An increase in the production to 900 tons a day was contemplated. There was approximately 300 acres of unmined coal tributary to this opening.

SMOKE RUN. VIOLA MINE.

Sample.—Semibituminous coal; Windber field; analyses No. 11748, 11749, 11750, 11751, W18355, W18356, W18357, W18358, and W18359 (pp. 89, 90).

Mine.—Viola, a slope mine in Gulic Township, Clearfield district, 3½ miles southeast of Smoke Run, on the Little Muddy Run branch of the Pennsylvania Railroad.

Coal bed.—Lower Kittanning, Miller, or B. Carboniferous age, Allegheny formation. Average thickness, about 5 feet 4 inches. The bed is practically level. Roof, "draw slate" 18 inches thick, overlain by sandstone; floor, hard smooth fire clay. Cover, 100 to 125 feet.

The bed was measured and sampled at three points in the mine by L. M. Jones on February 23, 1911, as described below:

Sections of coal bed in Viola mine.

Section	A		B		C	
Laboratory No.	11748		11749		11750	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, soft and coarse	0	5	..	..	0	10
Coal, soft and fine	1	4	1	4	0	7
Coal, bony	..	..	0	¼	..	..
Coal	..	..	0	4	..	..
Coal, bony	[a]0	10	[a]0	10	[a]1	0
Coal, soft and fine	2	8	0	10	2	3½
Bone (local)	..	..	..	..	0	½
"Sulphur" band	0	½	[a]0	¾	..	..
Coal, soft	0	4½	0	11½	0	7½
"Sulphur" band	..	..	[a]0	¾	..	..
Coal, soft and dirty	..	..	0	7	..	..
Floor, fire clay.						
Thickness of bed	5	8	5	¼	5	4½
Thickness of coal sampled	4	10	4	¾	4	4½

[a] Not included in sample.

Section A (sample 11748) was measured near the face of ninth left heading beyond room 18, 1,300 feet from the main haulage way.

Section B (sample 11749) was measured at the face of the second slant to the right near room 3.

Section C (sample 11750) was measured at the face of the main entry, 4,750 feet southwest of the mine mouth.

A composite sample was made by combining face samples 11748, 11749, and 11750. The results of an ultimate analysis of this sample are shown under laboratory No. 11751.

The bed was also measured and sampled at five points in the mine by P. M. Riefkin on March 7, 1911, as described below:

Sections of coal bed in Viola mine.

Section	A		B		C		D		E	
Laboratory No.	W18355		W18356		W18357		W18358		W18359	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	7	1	7½	1	7¾	0	9½	1	3½
"Sulphur"	..	..	..	..	..	..	0	½	0	½
Coal	..	..	..	..	..	..	0	10½	0	6½
Soft bone	[a]0	3	0	4½	[a]0	3	[a]0	2½	[a]0	4
Coal, bony	[a]0	8	0	5	[a]0	9	0	7½	[a]0	6
Coal	..	..	0	10½	..	..	..	..	..	..
"Blue binder"	..	..	[a]0	½	..	..	..	..	..	..
Coal	2	2½	1	3½	2	5½	2	2¾	1	10
"Sulphur"	0	½	[a]0	½	0	½	[a]0	½	[a]0	1
Coal	0	7½	0	4	0	5¾	0	4	0	4½
Floor, shale.										
Thickness of bed	5	4½	5	0	5	7½	5	1¾	5	0
Thickness of coal sampled	4	5½	4	11	4	7½	4	10¾	4	1

[a] Not included in sample.

Section A (sample W18355) was measured at the face of tenth left entry, 100 feet from room 12.

Section B (sample W18356) was measured near the face of the third slant entry, 100 feet above room 1.

Section C (sample W18357) was measured near the face of left heading 9.

Section D (sample W18358) was measured at the face of the main entry, 4,800 feet southwest of the mine mouth.

Section E (sample W18359) was measured at the face of the second slant entry, 100 feet above the third slant entry.

Notes.—The double-entry room-and-pillar system of mining is employed. At the time of sampling, the coal was undercut by hand and shot down with FFF black powder. There was one loading track at the tipple with a capacity of 20 empty and 17 loaded cars. There were no screens, the entire production being shipped as run-of-mine. Pickers were employed on the cars in loading. The average daily output was about 550 tons. There was 800 acres of unmined coal.

HUNTINGDON COUNTY.

ROBERTSDALE. ROBERTSDALE MINE.

Sample.—Semibituminous coal; Broad Top field; analyses Nos. 12115, 12116, 12117, 12118, 12119, and 12120 (p. 90).

Mine.—Robertsdale, a slope mine in the Broad Top district, at Robertsdale, on the East Broad Top railroad, with connections to the Pennsylvania Railroad at Mount Union.

Coal bed.—Fulton, Lower Kittanning, or B. Carboniferous age, Allegheny formation. Average thickness, 5 feet. Roof, dark, smooth shale; floor, hard, smooth fire clay.

The bed was measured and sampled at five points in the mine by H. I. Smith on April 25, 1911, as described below:

Sections of coal bed in Robertsdale mine.

Section	A		B		C		D		E	
Laboratory No.	12115		12116		12117		12118		12119	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Bone and shale	[a] 0	1½	[a] 0	8	[a] 0	5	[a] 0	1	..	..
Coal	1	4	0	2	0	6	1	9	0	8
Coal, bony	[a] 0	1	[a] 0	¼	[a] 0	1	..	..	..	..
Coal	0	2½	0	2	0	2	..	..	..	..
Coal, bony	[a] 0	2½	[a] 0	¼	0	1	..	..	0	¼
Coal	0	3	0	8	1	1	..	..	0	3¾
Coal, gray	0	⅛	0	¼	0	¾	0	½	..	..
Coal	0	11	0	11	1	0	0	8½	1	½
"Middle rock"	[a] 1	1	[a] 0	8	[a] 0	6½	[a] 0	5	[a] 0	5
Coal	..	..	..	..	0	1	..	..	..	..
Bone and coal	[a] 0	2	[a] 0	2	[a] 0	1½	[a] 0	2	[a] 0	1
Coal	1	2½	1	2½	1	9½	1	4	1	0
"Sulphur" and bone	[a] 0	1½	0	¼	[a] 0	2	[a] 0	1	0	⅛
Coal	0	6½	0	7	..	..	0	5	0	4
Bone and "sulphur"	..	..	[a] 0	½	..	..	[a] 0	3	[a] 0	1
Floor, hard fire clay.										
Thickness of bed	6	3⅛	5	4	6	1¼	5	3	3	11⅝
Thickness of coal sampled	4	5⅝	3	9	4	9¼	4	3	3	4⅝

[a] Not included in sample.

Section A (sample 12115) was measured at the face of north heading 6.

Section B (sample 12116) was measured at the face of the main west heading.

Section C (sample 12117) was measured at the face of south heading 6.

Section D (sample 12118) was measured at the face of south heading 8.

Section E (sample 12119) was measured at the face of south heading 5.

A composite sample was made by combining face samples 12115 to 12119, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 12120.

Notes.—At the time of sampling the coal was undercut by hand and shot down with FFFF and FFF black powder. At the tipple was one loading track with a capacity of 50 empty and 50 loaded cars. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. The mine had a capacity of about 900 tons a day with an average daily output of 825 tons, two-thirds of which was from advance workings. There was approximately 500 acres of unmined coal. The slope is connected under ground with the Woodvale shaft.

WOODVALE. WOODVALE MINE.

Sample.—Semibituminous coal; Broad Top field; analyses Nos. 12121, 12122, 12123, 12124, and 12125 (pp. 90, 91).

Mine.—Woodvale, a shaft mine in the Broad Top district at Woodvale, on the East Broad Top railroad, with connections to the Pennsylvania Railroad at Mount Union.

Coal bed.—Fulton, Lower Kittanning, or B. Carboniferous age, Allegheny formation. Average thickness, 5 feet. Roof, shale, overlain by sandstone; floor, fire clay.

The bed was measured and sampled at four points in the mine by H. I. Smith on April 24, 1911, as described below:

Sections of coal bed in Woodvale mine.

Section	A		B		C		D	
Laboratory No.	12121		12122		12123		12124	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	7½	1	7½	1	8¼	0	7
Mother coal and "sulphur"	0	⅜	..	..	0	½	0	¼
Coal	0	2¼	..	..	0	2	0	11¼
Bony coal	[a] 0	½	0	¼	0	⅝	0	¼
Coal	0	5	0	10	0	9	0	9½
Bony coal and "sulphur"	..	..	..	..	..	..	[a] 0	1
Coal	..	..	..	..	..	..	0	1½
Bony coal	0	¾	..	..	[a] 0	1	[a] 0	1
Coal	0	10¼	..	..	[a] 0	1½	0	10¼
"Middle rock"	[a] 0	7½	[a] 0	7½	[a] 0	5½	[a] 0	5
Bony coal, gray	..	..	[a] 0	2	0	1½	[a] 0	2
"Sulphur"	..	..	[a] 0	½	..	..	..	..
Coal	..	..	..	..	..	..	0	4
Soft parting	..	..	..	..	..	..	0	⅜
Coal	1	7½	0	9	0	10	0	10¾
Bony coal and "sulphur"	..	..	[a] 0	1½	[a] 0	1½	0	¼
Coal	..	..	0	4½	0	4	0	7
Floor, fire clay.								
Thickness of bed	4	5⅝	4	6¾	4	9⅜	5	10⅞
Thickness of coal sampled	3	9⅝	3	7¼	3	11⅞	5	1⅞

[a] Not included in sample.

Section A (sample 12121) was measured at the face of first south heading.

Section B (sample 12122) was measured at the face of the third south or upcreek heading.

Section C (sample 12123) was measured at the face of the second west tunnel.

Section D (sample 12124) was measured at the face of No. 7 or Bolinger heading.

A composite sample was made by combining face samples 12121 to 12124, inclusive, The results of an ultimate analysis of this sample are shown under laboratory No. 12125.

Notes.—At the time of sampling the coal was undercut by hand and broken down with FFFF and FFF black powder. There were two loading tracks at the tipple with a capacity of 50 empty and 50 loaded cars. The tipple was equipped with bar screens. The entire output was shipped as run-of-mine coal. Pickers were employed on the cars in loading. The daily output was 600 tons, which was from both advance workings and from pillars. There was approximately 800 acres of unmined coal. This mine is connected underground with the Robertsdale slope mine.

INDIANA COUNTY.

CLYMER. EMPIRE M (MCKEAN) MINE.

Sample.—Bituminous coal; Punxsutawney field; analyses Nos. 12219, W19678, W19680, W19682, W19685, and W19687 (p. 91).

Mine.—Empire M (McKean,) a drift mine 1½ miles north of Clymer, on the New York Central Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet. Roof hard, smooth shale; floor, fire clay.

The bed was measured and sampled at five points in the mine by P. M. Riefkin on April 29, 1911, as described below:

Sections of coal bed in Empire M (McKean) mine.

Section	A		B		C		D		E	
Laboratory No.	W19678		W19680		W19682		W19685		W19687	
	Ft.	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*
Roof, shale and bone.										
Coal	0	11	0	11	0	8¾	1	0	1	½
Mother coal	..	..	..	..	0	⅜	..	..	..	..
Coal	..	..	..	..	0	4¼	..	..	..	..
Cannel coal	0	1	0	1½	0	¼	0	¾	0	½
Coal	0	8	1	0	0	8¾	0	9	..	..
"Sulphur," soft	..	..	..	..	0	¼	Streak.		..	..
Coal	..	..	..	..	0	4¼	0	5½	..	..
"Sulphur," hard	0	¼	0	¼	[a] 0	⅜	..	..	..	..
Mother coal	..	..	..	..	..	..	0	½	..	..
Coal	1	6½	0	7½	0	7½	1	½	1	6½
"Sulphur"	..	..	Streak.		Streak.		..	..	0	⅜
Mother coal	..	..	..	..	..	..	0	1	..	..
Coal	..	..	0	6	0	4¾	..	..	0	7½
Floor, soft fire clay, smooth.										
Thickness of bed	3	2¾	3	2¼	3	3½	3	5¼	3	3⅜
Thickness of coal sampled	3	2¾	3	2¼	3	3⅛	3	5¼	3	3⅜

[a] Not included in sample.

Section A (sample W19678) was measured at the face of room 56, off right entry 2, off the main entry, 4,000 feet east of the mine mouth.

Section B (sample W19680) was measured at the corner of a crosscut at room 40, off right entry 2, off the main entry, 3,000 feet southeast of the mine mouth.

Section C (sample W19682) was measured at the corner of the pillar of room 44, off right entry 1, off the main entry, 2,500 feet west of the mine mouth.

Section D (sample W19685) was measured near the face of the first parallel off the south heading, off right entry 1, off the main entry, 2,800 feet southwest of the mine mouth.

Section E (sample W19687) was measured at the face of the third parallel off the south heading, off right entry 1, off the main entry, 3,000 feet northwest of the mine mouth.

A composite sample was made by combining face samples W19678, W19680, W19685, and W19687. The results of an ultimate analysis of this sample are shown under laboratory No. 12223.

Notes.—At the time of sampling the coal was undercut by hand and shot down with FFFF black powder. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track with a capacity of 25 loaded and 50 empty cars. The mine was equipped to produce 700 tons a day; the average daily output was 360 tons, a large part of which was from advance workings. There was about 1,200 acres of unmined coal tributary to this opening.

CLYMER. EMPIRE R MINE.

Sample.—Bituminous coal, Punxsutawney field; analyses Nos. 12219, W19679, W19681, W19683, W19684, and W19686 (p. 91).

Mine.—Empire R, a drift mine, 1 mile north of Clymer on the New York Central & Hudson River Railroad.

Coal bed.—Lower Kittanning or B. Carboniferous age, Allegheny formation. Average thickness, 3 feet; cannel coal is persistent throughout the bed. Roof, smooth shale; floor, hard, smooth fire clay.

The bed was measured and sampled at five points in the mine by P. M. Riefkin on April 29, 1911, as described below:

Sections of coal bed in Empire R mine.

Section	A		B		C		D		E	
Laboratory No	W19679		W19681		W19683		W19684		W19686	
Roof, shale and bony coal.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	8¼	..	..	0	5	0	4	..	..
"Sulphur" and mother coal	0	⅛	..	..	Streak.		0	⅛	..	..
Coal	0	5	1	⅝	0	7¼	0	7	0	8¾
Cannel coal, gray	0	¾	0	⅜	0	1	0	¾	0	1¼
Coal	0	7	0	7½	0	11¼	0	6½	..	..
"Sulphur" and mother coal	[a] 0	⅝	..	..	Streak.		Streak.		..	..
Coal	0	2	..	..	0	4½	0	10½	..	..
"Sulphur"	..	..	..	..	0	⅜	0	¼	..	..
Mother coal	0	¼	Streak.		..	..	..	..	..	..
Coal	1	2¼	1	5½	1	5½	0	9½	2	4½
Floor, hard fire clay, smooth.										
Thickness of bed	3	2¼	3	2	3	10⅞	3	2⅝	3	2½
Thickness of coal sampled	3	1⅝	3	2	3	10⅞	3	2⅝	3	2½

[a] Not included in sample.

Section A (sample W19679) was measured at a cross-cut at the corner of room 47, off left entry 1 off the main entry, 4,700 feet southeast of the mine mouth.

Section B (sample W19681) was measured on the pillar at room 28, off left entry 2 off the main entry, 2,200 feet east of the mine mouth.

Section C (sample W19683) was measured at the face of room 3, off right entry 1 off the main entry, 1,100 feet south of the mine mouth.

Section D (sample W19684) was measured at the face of room 11, off left entry 5 off the main entry, 1,900 feet southeast of the mine mouth.

Section E (sample W19686) was measured near the face of room 43, off left entry 4 off the main entry, 3,100 feet from the mine mouth.

A composite sample was made by combining face samples W19679, W19683, W19684, and W19686. The results of an ultimate analysis of this sample are given under laboratory No. 12219.

Notes.—At the time of sampling the coal was undercut by hand and shot down with FFFF black powder. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track with a capacity of 24 empty and 24 loaded cars. The mine was equipped to produce 500 tons a day and had a daily average production of 275 tons. About 75 per cent of the coal was derived from pillars. There was approximately 235 acres of unmined coal tributary to this entry.

GLEN CAMPBELL. INDIANA NO. 6 MINE.

Sample.—Bituminous coal; Punxsutawney field; analyses Nos. 12102, 12103, 12104, 12105, 12106, and 12107 (p. 92).

Mine.—Indiana No. 6, a drift mine at Glen Campbell, in Montgomery Township, 2½ miles north of Huvershurst Junction on the New York Central & Hudson River Railroad. The mine is connected with the main line of the New York Central by the Huvershurst & Southwestern Railroad.

Coal bed.—E or Upper Freeport. Average thickness, about 4 feet 10 inches. Roof, shale; floor, hard, smooth fire clay. Cover at points of sampling, 100 to 225 feet. The bed was sampled at five points in the mine by P. M. Riefkin on April 25, 1911, as described on the following page.

Sections of coal bed in Indiana No. 6 mine.

Section	A		B		C		D		E	
Laboratory No	12102		12103		12104		12105		12106	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, bony	[a]0	3	[a]0	9	[a]0	6	[a]0	7¼	[a]0	5¾
Coal	1	4	1	8	1	10	1	5	0	7
"Sulphur"	..	..	..	..	..	..	[a]0	½	..	..
Mother coal	0	¼	0	¼	0	¾	..	..	0	¼
Coal	..	..	..	..	0	3	..	..	1	4
Mother coal	..	..	..	..	0	¾	..	..	0	⅜
Coal, hard	2	0	1	9	..	..	..	..	..	..
Coal	..	..	..	..	1	6	2	1	1	6¼
Coal, bony	[a]0	¾	[a]0	1½	[a]0	1½	[a]0	1	[a]0	1
Coal	0	4	0	5	0	5	0	5	0	6¾
Coal, bony	[a]0	3¾	[a]0	1½	[a]0	2½	[a]0	1	[a]0	3
Floor, clay.										
Thickness of bed	4	3¾	4	10¼	4	11½	4	8¾	4	10⅜
Thickness of coal sampled	3	8¼	3	10¼	4	1½	3	11	4	⅝

[a] Not included in sample.

Section A (sample 12102) was measured at the face of left heading 7, off the main entry, 3,000 feet northwest of the mine mouth.

Section B (sample 12103) was measured at the face of room 10, off left entry 1, off the main heading, 1,000 feet northeast of the mine mouth.

Section C (sample 12104) was measured on the rib near the face of room 14 in right heading 7, off the main entry, about 2,000 feet northwest of the mine mouth.

Section D (sample 12105) was measured at the face of left heading 6, off the main entry, about 2,200 feet southwest of the mine mouth.

Section E (sample 12106) was measured near the face of room 1, off right heading 8, off the main entry, about 2,300 feet northwest of the mine mouth.

Notes.—The mine is worked on the room-and-pillar system. At the time of sampling, FFF black powder was used both for breaking the coal and brushing the roof or floor. The coal was undercut by hand. The output was 350 tons a day, with a capacity of 550 tons. About 40 per cent of the coal mined was from pillars and about 60 per cent from advance workings. There was about 100 acres of coal tributary to this opening.

HOMER CITY. TEARING RUN MINE.

Sample.—Bituminous coal; Punxsutawney field; analyses Nos. 12373, W20428, W20429, W20430, W20431, and W20432 (pp. 92, 93).

Mine.—Tearing Run, a drift mine, 1 mile northwest of Homer City, on the Pennsylvania Railroad.

Coal bed.—E, or Upper Freeport. Carboniferous age, Allegheny formation. Roof, shale about 10 to 12 inches thick, overlain by sandstone; floor, hard, smooth shale. Average thickness, 5 feet 6 inches. There is a persistent binder of bony coal about 15 inches below the shale roof.

The bed was measured and sampled at five points in the mine by P. M. Riefkin on June 9, 1911, as described below:

Sections of coal bed in Tearing Run mine.

Section	A		B		C		D		E	
Laboratory No	W20428		W20429		W20430		W20431		W20432	
Roof, sandstone and gray shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	3	1	3	1	5½	1	4½	1	6
"Sulphur"	[a]0	¾	[a]0	½	..	..	..	..	..	..
Coal	..	..	0	3	..	..	..	..	..	..
Bony coal	..	..	[a]0	10	[a]0	11	[a]0	9½	[a]0	8¾
Coal	1	11½	1	6¾	1	7¾	1	1½	1	3½
"Sulphur"	..	..	0	¼	Streak.		0	¼	0	⅛
Coal	..	..	..	..	..	..	..	..	0	6
"Sulphur"	..	..	..	..	..	..	..	..	0	¼
Mother coal	0	½	..	..	..	..	..	..	..	..
Coal	0	4½	2	0	2	0	2	8	1	11½
Floor, shale.										
Thickness of bed	3	8¼	5	11½	6	¼	5	11¾	6	⅛
Thickness of coal sampled	3	7½	5	1	5	1¼	5	2¼	5	3⅜

[a] Not included in sample.

Section A (sample W20428) was measured on the rib of room 10, off left entry 1, off the main heading.

Section B (sample W20429) was measured at the face of right entry 2, off the main entry.

Section C (sample W20430) was measured on the rib near the face of left entry 2, off the main entry.

Section D (sample W20431) was measured on stump No. 4, right entry 1, off the main entry.

Section E (sample W20432) was measured at the "shoo fly" (cut-through), 100 feet beyond left entry 3, off the main entry.

A composite sample was made by combining face samples W20428, W20429, W20430, and W20432. The results of an ultimate analysis of this sample are shown under laboratory No. 12373.

Note.—At the time of sampling the coal was undercut with machines and by hand, and shot down with FFF and FFFF black powder. At the tipple there was one loading track, with a capacity of 17 empty and 17 loaded cars. There were no screens, the entire output being shipped as run-of-mine. Pickers were employed on the cars in loading. The mine had a capacity of 500 tons a day and an average daily output of about 350 tons, of which the larger part was from advance workings. An increase in the output to about 500 tons was contemplated. There was approximately 400 acres of unmined coal tributary to this entry.

JEFFERSON COUNTY.

SYKESVILLE. SYKESVILLE MINE.

Sample.—Bituminous (coking) coal; Punxsutawney field; analyses Nos. 12455 and 12458, and 12457 and 12471 (p. 93).

Mine.—Sykesville, a shaft mine 1 mile south of Sykesville, on the Bloomsburg & Sullivan Railroad.

Coal bed.—Lower Freeport or D. Carboniferous age, Allegheny formation. Average thickness, 5 feet 6 inches; dip, 2° southeast. The main roof is a strong sandstone which in the south workings is underlain by shale. In the north workings there is no shale and in places the sandstone cuts the coal entirely out. The immediate floor, a hard clay, is separated from a sandstone of poor quality by 4 inches of brown limestone. Cover at points of sampling, about 300 feet.

The bed was measured and sampled at two points in the mine, and the roof coal above the bed was measured and sampled at two points by H. I. Smith and J. T. Ryan, on July 24, 1911, as described below:

Sections of coal bed in Sykesville mine.

Section	A		B	
Laboratory No.	12455		12458	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*
Bony coal	0	8½	0	8
Coal	0	8½	0	7½
Cannel-like bone	0	5	0	3
Coal	..	..	1	11
Bony coal	0	1	0	½
Coal	3	1	1	3½
"Mining slate"	[a]0	1½	[a]0	1½
Coal	0	9	0	9½
Floor, clay.				
Thickness of bed	5	10½	5	8½
Thickness of coal sampled	5	9	5	7

[a] Not included in sample.

Section A (sample 12455) was cut from the pillar at the last cut-through between eighth left main and the back heading, off main south heading.

Section B (sample 12458) was measured at the face of the third right butt heading off the eighth left, off the main south heading.

Sections of roof coal in Sykesville mine.

Section	A		B	
Laboratory No.	12457		12471	
Shale.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	1	..	..
Bony coal	0	1	..	..
Coal	0	5¾	..	..
Shale	[a]0	1	..	..
Coal	0	1½	..	..
"Sulphur"	0	¼	..	..
Coal	0	4	..	..
Shale	[a]1	9	..	..
Coal	0	10	0	8
Shale	[a]0	3	[a]0	2½
Coal	0	7	..	..
Bone	0	2	0	11
Coal	0	10½	1	½
Shale	[a]0	4½	[a]0	5
Lower Freeport bed.				
Thickness of bed	6	½	..	..
Thickness of coal sampled	3	7	2	7½

[a] Not included in sample.

Section A (sample 12457) was measured in a cavity in the roof between the third right butt and back heading, off the eighth main off the main south heading.

Section B (sample 12471) was measured in a cavity in the roof on the third right butt heading off the eighth left main, about 200 feet from the face of the main heading.

Notes.—The coal is mined by the room-and-pillar system. At the time of sampling the system in vogue was to drive the entries to the boundary line, turning the room necks as the entry was driven, and then drive the rooms and pull the ribs on the retreating system. The coal was undercut with compressed-air punching machines and broken down with a permissible explosive. The coal was picked on the cars. None of the coal was shipped as run-of-mine. Two-thirds of the coal passed over a 2½ by 4 inch screen. All the screenings were crushed and coked, about 600 tons being coked daily. There were two loading tracks with a capacity of 15 loaded cars and 15 empty cars. The daily output was 1,200 tons, all from advance workings. About 800 acres of this tract remained to be mined.

LACKAWANNA COUNTY.

DUNMORE. SLOAN MINE.

Sample.—Anthracite coal; Northern field; analysis No. 11440 (p. 93).

Mine.—Sloan, Dunmore, about 3 miles east of Scranton.

Coal bed.—Dunmore No. 2. Carboniferous age, Allegheny formation. The bed was sampled at one point by N. H. Darton on December 5, 1910. The sample represents 7 feet of coal. The sample was taken in connection with investigations of the occurrence of gases in coal beds.

LUZERNE COUNTY.

PITTSTON. COLLIERY NO. 14.

Sample.—Anthracite coal; Northern field; analysis No. 11441 (p. 93).

Mine.—Colliery No. 14, a shaft mine 2 miles southwest of Pittston, on the Erie Railroad.

Coal bed.—Pittston. Carboniferous age, Allegheny formation. Thickness, about 13 feet. A sample was taken by N. H. Darton on November 21, 1910, in the last chamber at the end of the Brannagan slope. The sample represents the full thickness of the bed, and does not contain any impurities, being all marketable coal.

Notes.—The mine is opened by slope, drift, and shaft. At the time of sampling the coal was mined by hand. The mine employed about 1,700 men.

WILKES-BARRE. DORRANCE MINE.

Sample.—Anthracite coal; Northern field; analysis No. 11782 (p. 93).

Mine.—Dorrance; a shaft mine in Wilkes-Barre Township about 1 mile west of Wilkes-Barre, with rail connections to the Lehigh Valley Railroad.

Coal bed.—Red Ash. Carboniferous age, Allegheny formation. Thickness, about 12 feet, all of which is marketable coal. Roof, soft sandstone and sandy shale; floor, fire clay. The sample was taken by N. H. Darton at the end of the first west gangway, 600 feet northwest of the shaft, and represents the entire section across the face.

Notes.—The mine is opened by a shaft 1,127 feet deep and the coal is mined by the pillar-and-chamber system. At the time of sampling the mine had an average production of 1,800 tons a day.

SOMERSET COUNTY.

ACOSTA. BELMONT No. 1 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12209, W19536, W19537, W19538, W19539, and W19543 (pp. 93, 94).

Mine.—Belmont No. 1, a drift mine in the Somerset district, one-quarter mile north of Acosta on the Boswell branch of the Baltimore & Ohio Railroad.

Coal bed.—C′, or Upper Kittanning. Carboniferous age, Allegheny formation. Average thickness, 3 feet 4 inches. Roof gray-black shale about 18 feet thick; floor, shale with an irregular surface.

The bed was measured and sampled at five points in the mine by G. S. Pope and E. W. Miller, April 26, 1911, as described below:

Sections of coal bed in Belmont No. 1 mine.

Section	A		B		C		D		E	
Laboratory Nos	W19536		W19537		W19538		W19539		W19543	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	9½	0	9¼	0	5½	0	9½	0	9
Bone and shale	[a]0	1½	[a]0	1	..	..	0	¾	[a]0	1½
Coal	..	..	..	..	..	..	0	11¼	..	..
"Sulphur" soft ball	..	..	..	..	0	¾	0	¾	..	..
Coal	..	..	..	..	0	1½	0	1¼	..	..
"Sulphur" soft ball	..	..	..	..	..	..	0	¾	..	..
Mother coal	..	..	..	..	0	¾	..	..	..	..
Coal	..	..	..	..	0	2¼	..	..	..	..
Coal (breast harder than rest of section)	..	..	..	..	0	3¼	..	..	..	..
Coal	2	7	2	7½	2	7½	1	3	2	4
Floor, shale.										
Thickness of bed	3	6	3	5¾	3	9½	3	3¼	3	2½
Thickness of coal sampled	3	4½	3	4¾	3	9½	3	3¼	3	1

[a] Not included in sample.

Section A (sample W19536) was measured at the face of room 4 off the main heading, 1,300 feet from the mine mouth.

Section B (sample W19537) was measured at the face of the third left entry, 60 feet from the main entry.

Section C (sample W19538) was measured at the face of room 3 off the first right entry.

Section D (sample W19539) was measured at the face of the second left entry, 250 feet from the main entry.

Section E (sample W19543) was measured at the face of the main heading, 1,550 feet from the mine mouth.

Notes.—At the time of sampling the coal was overcut by hand in the top of the bed, and FFFF and FFF black powder was used in breaking it down. There was one loading track with a capacity of 16 cars. There were no screens, the entire output being shipped as run-of-mine. Pickers were employed on the cars in loading. The coal is soft and friable. The mine was comparatively new, having started shipping coal in October, 1910. It had a capacity of 250 to 300 tons a day with an average daily output of 150 tons, the larger part of which was from advance workings. There was approximately 275 acres of unmined coal tributary to this opening.

BERLIN. CORONET NO. 3 MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 12214, W19532, W19533, W19534, W19535, and W19542 (p. 94).

Mine.—Coronet No. 3, a drift mine in the Somerset district, 1½ miles east of Berlin on the Berlin branch of the Baltimore & Ohio Railroad.

Coal bed.—"Smokeless" or Upper Freeport. Carboniferous age, Allegheny formation. Average thickness, 3 feet 6 inches. Roof, bony coal overlain by sandstone; floor, hard smooth sandstone.

The bed was measured and sampled at five points in the mine by G. S. Pope, April 25, 1911, as described below:

Sections of coal bed in Coronet No. 3 mine.

Section	A		B		C		D		E	
Laboratory No	W19532		W19533		W19534		W19535		W19542	
Roof, bony coal and sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	10	1	4½	1	6	1	0	2	6
Shale	0	1	..	..	..	..	..	..	[a] 0	2¾
Mother coal	..	..	0	¼	0	½	..	..	..	..
Coal	..	..	..	..	..	..	..	..	0	2¼
"Sulphur"	..	..	..	..	..	..	0	¼	0	¼
Coal	..	..	1	2	1	0	1	7	0	3
Shale	..	..	[a] 0	¾	[a] 0	1½	[a] 0	2	..	..
"Sulphur"	..	..	..	..	..	..	..	..	0	¼
Coal	..	..	0	¾	..	..	0	3½	0	4¾
Bony coal	..	..	0	¼	..	..	0	⅛	..	..
Coal	0	10½	0	9	0	10½	0	6	..	..
Shale	..	..	..	..	..	..	..	..	[a] 0	¾
Floor, sandstone.										
Thickness of bed	3	9½	3	5½	3	6½	3	6⅞	3	8
Thickness of coal sampled	3	9½	3	4¾	3	5	3	4⅞	3	4½

[a] Not included in sample.

Section A (sample W19532) was measured at the face of the eighth left entry, 15 feet beyond room 15 and 2,950 feet from the mouth of the main entry.

Section B (sample W19533) was measured at the face of the sixth right entry, 125 feet from the main heading and 2,500 feet from the mouth of the main entry.

Section C (sample W19534) was measured at the face of room 13, seventh left entry, 2,450 feet from the mouth of the main entry.

Section D (sample W19535) was measured on the pillar between rooms 2 and 3, off the main air course between third and fourth right entries, 1,400 feet from the drift mouth.

Section E (sample W19542) was measured at the face of seventh right entry, 50 feet beyond room 8, 2,800 feet from the mouth of the main entry.

Notes.—At the time of sampling the coal was undercut by hand and shot down with FFF and FFFF black powder. At the tipple there was one loading track, with a capacity of 12 cars. There were no screens, the entire output being shipped as run-of-mine coal. Pickers were employed on the cars in loading.

The coal near the roof gradually becomes harder and merges into bone, without any distinct line of separation between the beds.

The mine was equipped to produce about 300 tons a day, and had an average daily output of 150 tons. The coal was derived from both advance and pillar workings. The mine had been in operation about six years.

CONFLUENCE. LINMER MINE.

Sample.—Bituminous coal; Somerset field; analysis No. 13631 (p. 94).

Mine.—Linmer; a drift mine about 4½ miles southeast of Confluence, on Whites Creek, near Beachly post office, on a branch of the Baltimore & Ohio Railroad.

Coal bed.—C′ or Upper Kittanning. Carboniferous (Pennsylvanian) age, Allegheny formation. Average thickness, about 4 feet 3 inches. Roof, sandstone; floor, hard clay.

The bed was measured and sampled by C. T. Lupton on March 29, 1912. The sample represented a 3-foot 6½-inch section of coal.

The sample was taken at the end of the back subentry, off main entry 1, at a point about 2,500 feet southeast of mine mouth.

ELK LICK. ENGLE MINE.

Sample.—Semibituminous coal; Windber field; analysis No. 13983 (p. 95).

Mine.—Engle; about 2½ miles east of Elk Lick on Pine Run.

Coal bed.—D (?) Carboniferous (Pennsylvanian) age; Allegheny formation. Average thickness, about 3 feet. Roof and floor, shale. The strata at this locality dip about 13° W. and strike N. 38° E.

The bed was measured and sampled by C. T. Lupton on April 2, 1912, as described below:

Section of coal bed in Engle mine.

Laboratory No.	13983	
	Ft.	*in.*
Roof, shale.		
Coal	2	4
Bone and coal alternating	[a]0	3
Coal	0	6½
Floor, shale.		
Thickness of bed	3	1½
Thickness of coal sampled	2	10½

[a] Not included in sample.

The sample was collected in a room in this "country bank," about 600 feet east of the mine mouth.

ELK LICK. GRASSY RUN NO. 1 MINE.

Sample.—Semibituminous coal; Somerset field; analysis No. 13664 (p. 95).

Mine.—Grassy Run No. 1, about 2½ miles northwest of Elk Lick, on a branch of the Baltimore & Ohio Railroad.

Coal bed.—Four-foot Carboniferous (Pennsylvanian) age; Monongahela formation; about 35 feet stratigraphically above the Pittsburgh bed. Average thickness, about 4 feet 6 inches. Roof, shale 1 foot 3 inches, overlain by "wild coal," floor, sandy bone.

The bed was measured and sampled at one point in the mine by C. T. Lupton on April 1, 1912, as described below:

Section of coal bed in Grassy Run No. 1 mine.

Laboratory No.	13664	
	Ft.	*in.*
Roof, shale.		
Coal	2	0
Bone	[a]0	1
Coal	2	6
Floor, sandy bone.		
Thickness of bed	4	7
Thickness of coal sampled	4	6

[a] Not included in sample.

The sample was taken in a room about 1,200 feet southwest from the mine mouth.

HOLSOPPLE. LENORE MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 15078, 15079, 15080, 15081, and 15082 (p. 95).

Mine.—Lenore, a shaft mine, one-eighth of a mile north of Holsopple station, on the Baltimore & Ohio Railroad.

Coal bed.—B or Miller. Carboniferous age, Allegheny formation. Thickness, 3 feet to 4 feet, fairly uniform. The bed has no regular shale or sulphur partings. The roof is a sandstone which does not fall or get mixed with the coal. Floor, hard smooth underclay and black "rash." Cover at points of sampling, 150 to 250 feet.

The bed was measured and sampled at four points in the mine by G. H. Deike and Edwin Higgins on November 6, 1912, as described below:

Sections of coal bed in Lenore mine.

Section	A		B		C		D	
Laboratory No.	15078		15079		15080		15081	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, hard, bright	0	7	0	9	0	9	0	8
Coal, dull gray	0	½	0	¼	0	1½	0	¼
Coal, soft, bright	1	1	..	...	0	11¾	0	8
"Sulphur"	[a]0	1	..	...	Streak.		0	1/16
Coal, soft, bright	1	7	2	9¾	1	2¼	1	7¾
Mother coal	..	...	..	...	0	¼	..	...
Coal, soft, bright	..	...	..	...	0	3	..	...
Floor, underclay.								
Thickness of coal bed	3	4½	3	7	3	3¾	3	1/16
Thickness of bed sampled	3	3½	3	7	3	3¾	3	1/16

[a] Not included in sample.

Section A (sample 15078) was measured on rib in right entry 1, 200 feet from main entry.

Section B (sample 15079) was measured at the face of south entry 3.

Section C (sample 15080) was measured 30 feet from the face of the main entry.

Section D (sample 15081) was measured 30 feet from the face of south entry 7.

A composite sample was made by combining samples 15079, 15080, and 15081. The results of an ultimate analysis of this sample are given under laboratory No. 15082.

Notes.—The mine is opened by a shaft 87 feet deep and the coal is mined by the room-and-pillar method. At the time of sampling the coal was undercut by compressed-air cutting machines and by hand and blasted down with FFF black blasting powder. A permissible explosive was used for brushing the floor and roof. The entire output was shipped as run-of-mine. Pickers were employed on the car. There were two loading tracks with a capacity of 20 empty cars and 30 loaded cars. The average daily output was 200 tons with a maximum day's run of 400 tons. The capacity was estimated to be 600 tons a day.

HOLSOPPLE. ONEIDA MINE.

Sample.—Semibituminous coal; Windber field; analyses Nos. 15073, 15074, 15075, 15076, and 15077 (p. 95).

Mine.—Oneida, a slope mine one-eighth of a mile north of Holsopple, on the Baltimore & Ohio Railroad.

Coal bed.—Known as the Upper Kittanning or C′, Carboniferous age, Allegheny formation. Thickness, 3 feet 6 inches to 4 feet; average, 3 feet 8 inches. Roof, heavy sandstone; floor, hard limestone. Particles from the roof or floor did not become mixed to any extent with the coal in loading.

The bed was measured and sampled at four points in the mine by G. H. Deike and Edwin Higgins on November 6 and 7, 1912, as described below:

Sections of coal bed in Oneida mine.

Section	A		B		C		D	
Laboratory No.	15073		15074		15075		15076	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, soft, bright, friable	0	9	0	11	0	11¼	1	0
Coal, hard, gray, bony	0	4	0	½	0	½	0	1
Coal, bright, friable	..	..	..	...	0	2	..	..
Coal, hard, gray	..	..	..	...	0	6½	..	..
Coal, hard, bright	2	3	1	7	1	9½	2	11
"Sulphur" streak	..	..	0	¼	0	½	..	..
Coal, hard, bright	..	..	0	11	..	..	..	..
Coal	..	..	..	..	0	1	..	..
Floor, limestone.								
Thickness of bed	3	4	3	5¾	3	7¼	4	0
Thickness of coal sampled	3	4	3	5¾	3	7¼	4	0

Section A (sample 15073) was measured on a pillar in room 6 off left entry 5

Section B (sample 15074) was measured at the face of room 3 off left entry 6.

Section C (sample 15075) was measured 15 feet from face of left entry 5.

Section D (sample 15076) was measured at the face of room 23 off left entry 3.

A composite sample was made by mixing face samples 15074, 15075, and 15076. The results of an ultimate analysis of this sample are given under laboratory No. 15077.

Notes.—At the time of sampling the coal was undercut by hand and with compressed-air punching machines and shot down with FFF black powder. Permissible explosives were used for blasting the roof or floor. The tipple was used both by the Oneida and Lenore mines but the coal was not mixed, as each mine had a separate dump. All coal was shipped as run-of-mine. Pickers were employed on the cars. There were two loading tracks at the tipple with a capacity of 20 empty and 30 loaded railroad cars. The average daily output was 200 tons, the maximum day's run being 300 tons.

JEROME. JEROME No. 2 MINE

Sample.—Semibituminous coal; Windber field; analyses Nos. 12210, W19638, W19639, and W19642 (p. 95).

Mine.—Jerome No. 2, a shaft mine in the Somerset district, at Jerome, on the Somerset & Cambria branch of the Baltimore & Ohio Railroad.

Coal bed.—C′, or Upper Kittanning, Carboniferous age, Allegheny formation. The coal has an average thickness of 6 feet (including 6 inches of bone). The bone and shale are persistent at the top of the bed and irregular in the body of the bed. The roof is a bony coal averaging 6 inches in thickness overlain by a limestone capping. Floor, hard smooth sandstone.

The bed was measured and sampled at one point in the mine on May 22, 1911, and at 3 points, on April 27, 1911, by G. S. Pope, as described below:

Sections of coal bed in Jerome No. 2 mine.

Section	A		B		C	
Laboratory No.	W19638		W19639		W19642	
Roof, bony coal and limestone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Bone and shale	[a] 0	5½	[a] 0	6½	[a] 0	4
Coal	1	1½	1	3	1	0
Bone, shale, and coal	[a] 0	9	[a] 0	1	[a] 0	11
Coal	4	2	4	2	3	9½
Floor, sandstone, hard.						
Thickness of bed	6	6	6	½	6	½
Thickness of coal sampled	5	3½	5	5	4	9½

[a] Not included in sample.

Section A (sample W19638) was measured at the face of south entry 7 off east entry 1½.

Section B (sample W19639) was measured at the face of south entry 4 off east entry 2.

Section C (sample W19642) was measured at the face of east entry 2.

Sample 12210 was measured at the face of east entry 1.

A composite sample was made by combining face samples W19638, W19639, and W19642. The results of an ultimate analysis of this sample are shown under laboratory No. 12224.

Notes.—In April, 1911, the coal was undercut with machines and by hand and was broken down with a permissible explosive. The mine was well equipped. The tipple had 4 loading tracks with a capacity of 80 cars. The coal was screened with bar screens 10 feet long, with 3-inch openings; 75 per cent of the coal passed through. The coal was hand picked both on the conveyor and on the car in loading. The mine had a capacity of 1,700 tons a day with an average daily output of 1,020 tons, which was largely from advance workings. It was planned to increase the production to about 1,500 tons. The operating company owned or controlled about 1,000 railroad cars.

PINEHILL. CONSOLIDATION NO. 112 MINE.

Sample.—Semibituminous coal; Somerset field; analyses Nos. 13981, 13982, and 14037 (p. 96).

Mine.—Consolidation No. 112, at Pinehill, on the Berlin branch of the Baltimore & Ohio Railroad.

Coal bed.—"Little Pittsburgh." Carboniferous (Pennsylvanian) age; in the upper part of the Conemaugh formation, about 147 feet stratigraphically below the Pittsburgh bed. Average thickness, about 3 feet 4 inches. Strata are flat-lying, with a maximum dip of about 5 per cent. Roof, shale grading into sandstone above; floor, carbonaceous shale with some clay.

The bed was sampled and measured by C. T. Lupton at two points on April 3, 1912, as described below:

Sections of coal bed in Consolidation No. 112 mine.

Laboratory Nos.	13981		13982	
Roof, sandy shale, grading into sandstone above.	*Ft.*	*in.*	*Ft.*	*in.*
Coal (usually not mined)	..	..	[a]0	7
Shale	..	..	[a]0	8
Coal	2	6	2	0
Bone, variable	0	¼	[a]0	½
Coal, with occasional small lenses of pyrite	1	¾	1	1
Floor, shale and clay.				
Thickness of bed	3	7	4	4½
Thickness of coal sampled	3	7	3	1

[a] Not included in sample.

Sample 13981 was taken in room 44, right subentry 8 off the west main entry, about 3,600 feet west of the mine mouth.

Sample 13982 was taken in room 8, right subentry 1 off left entry 12, about 5,000 feet southwest of the mine mouth.

A composite sample was made by combining face samples 13981 and 13982. The results of an ultimate analysis of this sample are shown under laboratory No. 14037.

PINEHILL. CONSOLIDATION NO. 113 MINE.

Sample.—Semibituminous coal; Somerset field; analysis No. 13984 (p. 96).

Mine.—Consolidation No. 113; at Pinehill, on the Berlin branch of the Baltimore & Ohio Railroad.

Coal bed.—"Stoner." Carboniferous age (Pennsylvanian) age; Conemaugh formation; about 290 feet stratigraphically below the Pittsburgh bed. Average thickness, about 4 feet. Roof, shale grading upward into sandstone.

The sample was collected by C. T. Lupton on April 3, 1912, from a mine car brought directly from room 2, right entry 10, about 3,700 feet southwest from the mine mouth. Information regarding the thickness of the bed as described below was furnished by C. W. Hoffa, superintendent of the mine.

Section of coal bed in Consolidation No. 113 mine, at Pinehill.

	Ft.	in.
Roof, shale, grading into sandstone above.		
Coal	3+	0
Shale (variable)	0	3
Coal	0	11
Floor (not stated).		
Thickness of bed	4	2

RALPHTON. RALPHTON NO. 3 MINE.

Sample.—Semibituminous coal; Somerset field; analyses Nos. W19627, W19628, W19629, W19630, and W19631 (p. 96).

Mine.—Ralphton No. 3, a drift mine one-half mile east of Ralphton on the Boswell branch of the Cambria and Somerset division of the Baltimore & Ohio Railroad.

Coal bed.—C′ or Upper Kittanning. Carboniferous age, Allegheny formation. The coal has an average thickness of 3 feet 5 inches. The roof is a strong gray shale between which and the main coal bed is a seam of roof coal 3 to 4 inches thick. The floor is a smooth, hard limestone.

The bed was measured and sampled at five points in the mine by G. S. Pope on April 29, 1911, as described below:

Sections of coal bed in Ralphton No. 3 mine.

Section	A		B		C		D		E	
Laboratory No	W19627		W19628		W19629		W19630		W19631	
Roof, shale.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Shale, bone, and coal	[a] 0	4½	[a] 0	3	[a] 0	4	[a] 0	3	[a] 1	4
Coal	..	..	0	1	..	..	..	..	..	..
Shale	[a] 0	4	0	¼	..	..	..	..	..	..
Coal	..	..	0	9	0	9¼	..	..	0	7½
Bone	..	..	0	½	0	½	..	..	0	½
Coal	3	3	2	7	2	6½	3	6½	2	8½
Floor, limestone.										
Thickness of bed	3	11½	3	8¾	3	8¼	3	9½	4	8½
Thickness of coal sampled	3	3	3	5¾	3	4¼	3	6½	3	4½

[a] Not included in sample.

Section A (sample W19627) was measured at the third crosscut off south entry 2, about 3,050 feet from the mine mouth.

Section B (sample W19628) was measured at the face of room 11 off the straight main entry, about 3,150 feet from the mine mouth.

Section C (sample W19629) was measured at the face of room 4 off right entry 6, about 2,800 feet from the mine mouth.

Section D (sample W19630) was measured at the face of room 29 off right heading 4, about 2,900 feet from the mine mouth.

Section E (sample W19631) was measured 20 feet inside the third crosscut off south entry 3, about 3,700 feet from the mine mouth.

Notes.—At the time of sampling the coal was undercut by hand and shot down with FFF and FFFF black powder. The tipple had one loading track with a capacity of 22 cars. There were no screens, the entire output being loaded as run-of-mine. Pickers were employed on the cars in loading. The mine had a capacity of 1,000 tons and an average daily output of 850 tons, most of which was from advance workings.

RALPHTON. RALPHTON NO. 4 MINE.

Sample.—Semibituminous coal; Somerset field; analyses Nos. 12202, 12218, W19632, W19633, W19635, W19636, and W19637 (p. 97).

Mine.—Ralphton No. 4, a drift mine, 1½ miles north of Ralphton, on the Baltimore & Ohio Railroad.

Coal bed.—C′ or Upper Kittanning. Carboniferous age, Allegheny formation. The coal has an average thickness of 3 feet 10 inches and is relatively free from partings. Roof, firm, smooth shale; floor, smooth, hard limestone.

The bed was measured and sampled at five points in the mine by G. S. Pope on April 28, 1911, as described below:

Sections of coal bed in Ralphton No. 4 mine.

Section	A		B		C		D		E	
Laboratory No	W19632		W19633		W19635		W19636		W19637	
Roof, smooth shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	3	3	10¾	3	7½	3	7	3	11
Hard gray coal inclined to bone	0	1	..	..	..	..	..	..	..	..
Coal	2	7½	..	..	..	..	..	..	..	..
Floor, hard smooth limestone.										
Thickness of bed	3	11½	3	10¾	3	7½	3	7	3	11
Thickness of coal sampled	3	11½	3	10¾	3	7½	3	7	3	11

Section A (sample W19632) was measured on a pillar between the south main heading and the air course opposite right entry 1.

Section B (sample W19633) was measured at the face of the south main entry.

Section C (sample W19635) was measured at the face of room 7 off the south main entry.

Section D (sample W19636) was measured on pillar 1 at the second "shoo-fly" (crossover) off main entry 1.

Section E (sample W19637) was measured at the face of left entry 4 off the south main entry.

Notes.—At the time of sampling the coal was undercut in the lower part of the bed by hand and was shot down with black powder. The tipple had one loading track with a capacity of 15 railroad cars. There were no screens, the output being loaded as run-of-mine. The mine had a capacity of 450 tons and an average daily output of 400 tons.

WASHINGTON COUNTY.

AVELLA. PENOBSCOTT MINE.

Sample.—Bituminous coal; Pittsburgh field; analyses Nos. 15673 and 15674 (p. 97).

Mine.—Penobscott, a drift mine, 2 miles west of Avella, on Wabash-Pittsburgh Terminal Railway, near State line.

Coal bed.—Pittsburgh. Carboniferous age, Monongahela formation. Thickness averages about 4½ feet where measured. In this vicinity this coal bed has been locally eroded and replaced by sandstone. The roof left in mining is coal, the top clay above the main bed of coal being weak.

The bed was measured and sampled at two points in the mine by D. D. Condit on January 8, 1913, as described below:

Sections of bed in Penobscott mine.

Section	A		B	
Laboratory No.	15673		15674	
Roof, coal 3 to 6 inches.	*Ft.*	*in.*	*Ft.*	*in.*
Clay	[a]1	1	[a]1	0
Coal	2	2½	2	3
Clay	[a]0	½	[a]0	¼
Coal	[a]0	3¾	[a]0	3½
Clay	[a]0	½	[a]0	¼
Coal	1	8½	1	7
Floor, clay and shale.				
Thickness of bed	5	4½	5	2
Thickness of coal sampled	3	11	3	10

[a] Not included in samples.

Section A (sample 15673) was measured in room 15, eighth left entry off main entry, 2,500 feet northwest of mine mouth. Cover at point of sampling, 80 feet.

Section B (sample 15674) was measured in a room off seventh right entry, 3,100 feet northeast of mine mouth. Cover, 70 feet.

BAIRD. SCHOENBERGER MINE.

Sample.—Bituminous coal; Pittsburgh field; analysis Nos. 11164, 11165, 11166, 11167, 11168, 11169 and 11170 (pp. 97, 98).

Mine.—Schoenberger, a drift mine at Baird, a station on the Monongahela division of the Pennsylvania Railroad.

Coal bed.—Pittsburgh, Carboniferous age, Monongahela formation. Average thickness, 5 feet 10 inches. The roof is a "draw slate" 8 inches thick, above which is a shale; 15 feet above the shale is the main cap rock. The floor is a shale, below which is a limestone. Dip, about 1 per cent southwest.

The bed was sampled and measured at six points in the mine by A. A. Straub on November 3, 1910, as described below:

Sections of coal bed in Schoenberger mine.

Section	A		B		C		D		E		F	
Laboratory No.	11164		11165		11166		11167		11168		11169	
	Ft.	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*
Roof, slate.												
Coal, bright	3	4½	2	7½	2	1	2	2¼	1	10¼	3	2½
"Sulphur" band	..	..	[a]0	¾	0	½	[a]0	½	0	½	..	..
Coal, bright	..	..	0	9¼	0	11¾	0	2½	0	7¼	..	..
Shale band	[a]0	½	..	..	[a]0	¼	..	..	..	..	..	..
"Sulphur" band	..	..	0	¼	..	..	0	¼	0	¼	..	..
Coal, bright	0	2¼	0	2¼	0	2½	0	1	..	..	..	..
"Sulphur" band	..	..	..	..	..	..	0	½	..	..	..	..
Coal, bright	..	..	..	..	..	..	0	8½	0	9¼	..	..
Shale band	[a]0	¾	[a]0	¾	[a]0	¼	[a]0	¼	[a]0	½	[a]0	½
Coal, bright	..	..	0	1¼	..	..	0	3	0	2¼	0	1¼
"Sulphur" band	..	..	0	¼	..	..	..	..	..	..	..	..
Shale band	..	..	..	..	..	..	[a]0	¼	[a]0	½	[a]0	¾
Coal, bright	..	..	1	2	..	..	0	6½	1	6½	..	..
"Sulphur" band	..	..	0	¼	..	..	0	½	0	¼	..	..
Coal, bright	1	10¼	0	9¼	1	10½	1	5½	0	5¼	1	9
Floor, shale and limestone.												
Thickness of bed	5	6¼	5	9¾	5	2¾	5	7½	5	6¾	5	2
Thickness of coal sampled	5	5	5	8¼	5	2¼	5	6½	5	5¾	5	¾

[a] Not included in sample.

Section A (sample 11164) was measured at the face of room 10, entry 32 off face entry 12, about 4,000 feet southeast of the mine mouth.

Section B (sample 11165) was measured at the face of room 4, entry 32 off face entry 11, about 4,000 feet southeast of the mine mouth.

Section C (sample 11166) was measured at the face of the right main entry, about 7,000 feet south of the mine mouth.

Section D (sample 11167) was measured at the face of room 11, entry 32 off the right main entry, about 6,000 feet south of the mine mouth.

Section E (sample 11168) was measured at the face of face entry 11, about 4,800 feet southeast of the mine mouth.

Section F (sample 11169) was measured on a pillar, in right entry 29 off the main entry, about 5,500 feet south of the mine mouth.

Notes.—The coal is mined by the double entry, room-and-pillar system. At the time of sampling electric chain-cutting machines were used and the coal was broken down with FF black powder. The mine had a capacity of about 3,000 tons a day, 75 per cent of which was from advance workings. There were 4 loading tracks with a capacity of 65 cars at the tipple. Pickers were employed on the cars when coal was being loaded. About 10 per cent of the coal was shipped as run-of-mine and remainder was screened to various commercial sizes. There was about 250 acres of unmined coal tributary to this drift mouth.

FINLEYVILLE. CINCINNATI MINE.

Sample.—Bituminous coal; Pittsburgh field; analyses Nos. 17082, 17083, 17084, and 17085 (p. 98).

Mine.—The Cincinnati mine is opened by a drift about two miles northeast from Courtney and a manway at Mingo 2 miles southeast of Finleyville.

Coal bed.—Pittsburgh, Carboniferous age, Monongahela formation. Thickness, 4 feet 8 inches to 6 feet 8 inches, fairly uniform. In the center of the bed are two characteristic clay partings about three inches apart. The roof is a "draw slate," over which there is a roof coal and shale. The floor is an underclay, beneath which is a limestone bedrock.

The bed was measured and sampled at three points in the mine by H. I. Smith, H. D. Mason, jr., and W. A. Raudenbush on May 7, 1913, as described below:

Sections of coal bed in Cincinnati mine.

Section	A		B		C	
Laboratory No	17082		17083		17084	
Roof, "draw slate."	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	4½	1	6½	1	7½
Bony coal	0	½	0	½	0	1
Coal	1	9¾	0	10	1	7
Mother coal and "sulphur"	0	¾	0	½	..	..
Coal	0	3¼	1	½	..	..
Shale binder	Streak.		[a]0	¼	0	¼
Coal	0	3¼	[a]0	3¾	0	2¾
Shale binder	0	¾	[a]0	¼	0	¾
"Sulphur" ball on one side	..	..	..	..	0	3
Coal	0	7¼	0	2	0	3¾
Mother coal	0	½	0	¼	0	¼
Coal	1	2	1	9	1	9
Bottom coal	..	..	[a]0	4	0	4½
Floor, underclay.						
Thickness of bed	5	8½	6	1½	6	3¾
Thickness of coal sampled	5	8½	5	5¼	6	3¾

[a] Not included in sample.

Section A (sample 17082) was measured 60 feet outby the last cut-through on butt entry 6 off face entry 14, about 6,200 feet northwest of the mouth of Mingo slope entry.

Section B (sample 17083) was measured 60 feet inby room 2 on butt entry 10 off face entry 14, about 6,800 feet northwest of the mouth of Mingo slope entry.

Section C (sample 17084) was measured inby the first crosscut on butt entry 12 off face entry 14, about 7,400 feet northwest of the mouth of Mingo slope entry.

A composite sample was made by mixing face samples 17082, 17083, and 17084. The results of an ultimate analysis of this sample are given under laboratory No. 17085.

Notes.—The coal is mined by the room-and-pillar system. At the time of sampling it was undercut with electric cutting machines in the bottom of the bed and was broken down with permissible explosives. The cuttings were loaded out with the coal. The "draw slate" is treacherous and must be broken down and loaded out after each cut of coal. The entire output of the mine went to a tipple on the Monongahela River. Although this mine is one of the first on the Monongahela River it still contained considerable coal.

MONONGAHELA CITY. CATSBURG MINE.

Sample.—Bituminous coal; Pittsburgh field; analyses Nos. 11157, 11158, 11159, 11160, 11161, 11162, 11163, 11172, 11541, and 12281 (pp. 98, 99.)

Mine.—Catsburg, a drift mine one-fourth of a mile south of Monongahela City with railroad connections to the Monongahela River division of the Pennsylvania lines.

Coal bed.—Pittsburgh. Average thickness, 5 feet 6 inches. Dip, 1 per cent southeast. The roof is a "draw slate," about 8 inches thick, above which is a fair quality of roof coal 6 to 12 inches thick. Floor, soft fire clay. The bed was measured and sampled at six points in the mine by J. J. Rutledge and A. A. Straub on November 1, 1910, as described below:

Sections of coal bed in Catsburg mine.

Section	A	B	C	D	E	F
Laboratory No.	11157	11158	11159	11160	11161	11162
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal, bright and hard	2 3	2 11½	2 9¾	3 1	2 8¾	3 2
"Sulphur" band	0 ½	.. ..	.. ..	.. ..	.. ..	.. ..
Coal	0 8½	.. ..	.. ..	.. ..	.. ..	.. ..
Shale, dark	*a*0 ½	*a*0 ¾	*a*0 ½	*a*0 ½	*a*0 ⅝	*a*0 ⅝
Coal, bright	0 2½	0 2¾	0 2¼	0 2⅜	0 2¼	0 2¼
Shale, dark	*a*0 ½	*a*0 1⅛	*a*0 ½	*a*0 ¾	*a*0 ⅝	*a*0 ¾
Coal, bright	2 2½	1 1½	1 1⅜	2 2	2 5¾	0 9¼
"Sulphur" band	.. ..	.. ..	0 ⅜	.. ..	.. ..	0 ½
Coal, bright	.. ..	.. ..	0 11½	.. ..	.. ..	1 5¼
Floor, fire clay.						
Thickness of bed	5 6	4 5⅝	5 2¼	5 6⅝	5 6	5 8⅝
Thickness of coal sampled	5 5	4 3¾	5 1¼	5 5⅜	5 4¾	5 7¼

a Not included in sample.

Section A (sample 11157) was measured at the face of sixty-sixth butt entry, 2½ miles northeast of the mine mouth.

Section B (sample 11158) was measured on the rib of room 17, seventy-fifth entry, 2½ miles northeast of the mine mouth.

Section C (sample 11159) was measured at the face of room 23, seventy-ninth butt entry, 2¾ miles northeast of the mine mouth.

Section D (sample 11160) was measured on the chain pillar at room 46, seventy-fourth butt entry, 2½ miles northwest of the mine mouth.

Section E (sample 11161) was measured at the face of the north second main entry, 2½ miles north of the mine mouth.

Section F (sample 11162) was measured at the face of room 101 on sixty-eighth butt entry, 2¾ miles northwest of the mine mouth.

Three cars of slack coal from this mine were shipped to the Pittsburgh experiment station for testing purposes. The car samples are designated as follows: Pittsburgh No. 113, laboratory No. 11172; Pittsburgh No. 131, laboratory No. 11541; Pittsburgh No. 181, laboratory No. 12281.

Notes.—The coal is mined by the double-entry, room-and-pillar system. At the time of sampling electric chain-cutting machines were used. The coal was shot down with FFF black powder, dynamite being used for brushing the roof. The mine had a daily production of about 875 tons, which was derived both from advance workings and pillars. Only a little of the coal was shipped as run-of-mine. There were 3 loading tracks, with a capacity of about 45 cars, at the tipple. Pickers were employed both in the mine and on the railroad cars when coal was loaded. About 33 per cent of the coal produced was screenings. There was about 1,400 acres of unmined coal tributary to this opening.

WESTMORELAND COUNTY.

GREENSBURG. No. 4 MINE.

Sample.—Bituminous coal; Pittsburgh field; Greensburg district; analysis Nos. 12265 and 12853 (p. 99.)

Mine.—No. 4; 4 miles north of Greensburg.

Coal bed.—Pittsburgh. Carboniferous age, Monongahela formation. The coal from this mine was sampled by E. R. Linkenhoker on June 7 and November 13, 1911, respectively, while the coal was being unloaded at the Bureau of Mines testing plant, Pittsburgh, Pa.

Sample 12265 represented a carload of lump coal (Pittsburgh No. 178).

Sample 12853 represented a carload of lump coal (Pittsburgh No. 254).

LUCESCO. LUCESCO MINE.

Sample.—Bituminous coal; Pittsburgh field; analyses Nos. 12393, 12394, 12395, 12396, and 12397 (p. 99).

Mine.—Lucesco, a drift mine in the Allegheny River district, near Lucesco, a post office at Kiskiminetas Junction, on the Conemaugh and Allegheny divisions of the Pennsylvania Railroad.

Coal bed.—Known as the Upper Freeport or E. Carboniferous age, Allegheny formation. The thickness is rather variable, ranging from 2 to 4 feet. The roof near the opening is a sandy shale of variable thickness, averaging 1½ feet. At the points where the samples were taken the roof is sandstone. The floor is an underclay, 1½ to 3 feet thick, underlain by limestone. The floor is taken up in the inner workings to get the necessary height and the material is packed in gob walls along the entries. The cover increases rapidly from the outcrop and rises to 300 feet at places.

The bed was measured and sampled at four points in the mine by L. M. Jones, on June 29, 1911, as described below:

Sections of the coal bed in the Lucesco mine.

Section	A		B		C		D	
Laboratory No.	12393		12394		12395		12396	
Roof, hard sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal with fine "sulphur" streaks	0	3½	1	4	..	..	..	..
Mother coal	..	..	0	¼	..	..	..	..
Coal, hard	1	10½	1	1¾	2	10	2	8½
Mother coal or shale	0	½	0	¼	..	..	[a]0	½
Coal	0	1	0	9¾	..	..	0	2
Shale and coal	[a]0	1	[a]0	1½	[a]0	1	0	½
Coal	0	6	0	4½	0	6	0	3
Shale and "sulphur"	[a]0	½	..	..	[a]0	2	[a]0	1½
Coal	0	7	..	..	0	4	0	4
Floor, fire clay.								
Thickness of bed	3	6	3	10	3	11	3	8
Thickness of coal sampled	3	4½	3	8½	3	8	3	6

[a] Not included in sample.

Section A (sample 12393) was cut from the face of the ninth left entry, 4,000 feet south of the mine mouth.

Section B (sample 12394) was cut from the face of the fifth left entry, 165 feet beyond room 46, 3,600 feet from the mine mouth.

Section C (sample 12395) was cut from the face of room 48, first right entry, 3,200 feet southeast of the mine mouth.

Section D (sample 12396) was cut from the face of room 20, third right entry, 2,300 feet southeast of the mine mouth.

A composite sample was made by mixing face samples 12393, 12394, 12395, and 12396. The results of an ultimate analysis of this sample are shown under laboratory No. 12397.

Notes.—At the time of sampling, the coal at this mine was undercut by hand and blasted with FFF black powder. From the mine opening 40 feet above the tipple floor a gravity incline led to the tipple, which extended over the loading track and the main line of the Pennsylvania Railroad, and was equipped to load the engines on the latter track. The daily output averaged 300 tons a day.

MADISON. KEYSTONE MINE.

Sample.—Bituminous coal, Pittsburgh field. Analyses Nos. 16270 and 16271 (p. 99).

Mine.—Keystone, a shaft mine at Madison.

Coal bed.—Pittsburgh. Carboniferous age, Monongahela formation. Thickness about 6½ feet.

Sample 16270 was taken from a car of slack and sample 16271 from a car of run-of-mine coal, by E. R. Linkenhoker while the cars were being unloaded at the Pittsburgh testing station.

SOUTH DAKOTA.

HARDING COUNTY.

BUFFALO. HILTON MINE.

Sample.—Lignite. Northwestern South Dakota field; analysis No. 13221 (p. 100.)

Mine.—Hilton, a drift mine near center of sec. 6, T. 20 N., R. 5 E., 10 miles north of Buffalo.

Lignite bed.—No name. Cretaceous or Tertiary age; Lance formation.

The bed was measured and sampled by E. M. Parks on October 4, 1911, as described below:

Section of lignite bed in the Hilton mine.

Laboratory No.	13221	
	Ft.	*in.*
Roof, lignite.	[a]1	11
Clay, gray	[a]0	6
Lignite	2	10
Clay	[a]0	1½
Lignite, brown, woody	4	4
Clay (with water) reported	[a]2	0
Lignite, reported	[a]2	0
Floor, clay.		
Thickness of bed	13	8½
Thickness of lignite sampled	7	2

[a] Not included in sample.

Note.—The mine was seldom worked. The sample was collected at the face of the drift entry, 120 feet from the outcrop at the mine mouth. The sample was fairly dry.

BUFFALO. OPEN PIT.

Sample.—Lignite. Northwestern South Dakota field; analysis No. 13220 (p. 100).

Mine.—Mendenhall; 18 miles east of Buffalo, in sec. 1, T. 17 N., R. 7 E.

Lignite bed.—Upper Cretaceous or Tertiary age; Lance formation.

The bed was measured and sampled by E. M. Parks on August 18, 1911, as described below:

Section of lignite bed in open prospect.

Laboratory No.	13220	
	Ft.	*in.*
Dirt, bituminous with coaly streaks [a]	0	5¼
Lignite, tough	0	5
Lignite, bony	0	2
Lignite, tough	0	9
Bone	0	1
Lignite	0	7
Clay	0	1
Lignite, tough, with two thin sandy partings	4	¾
Clay.[a]		
Thickness of bed	6	7
Thickness of lignite sampled	6	1¾

[a] Not included in sample.

The sample was collected from the face of prospect after about two feet of lignite had been removed, and was fairly dry.

Note.—This prospect was seldom worked.

BUFFALO. OPEN PIT.

Sample.—Lignite. Northwestern South Dakota field; analysis No. 13222 (p. 100).

Mine.—Mendenhall; 18 miles east of Buffalo in sec. 1, T. 17 N., R. 7 E.

Lignite bed.—Upper Cretaceous or Tertiary age, Lance formation.

The bed was measured and sampled by E. M. Parks on August 17, 1911, as described below:

Section of lignite bed in open prospect.

Laboratory No.	13222	
	Ft.	*in.*
Clay, brown	[a] 2	5
Lignite	[a] 0	4
Clay, laminated	[a] 1	1
Lignite, dirty	[a] 0	6
Dirt, bituminous	[a] 0	7
Lignite with bone interbedded	1	7
Shale with lignite interbedded	[a] 0	3
Lignite, dirty	0	3½
Shale	0	½
Lignite	4	4
Thickness of bed	11	5
Thickness of lignite sampled	6	3

[a] Not included in sample.

The sample was collected from the face of the stripping after about 2 feet of lignite had been removed.

Note.—This prospect was seldom worked.

RALPH. NEWCOMB MINE.

Sample.—Lignite; Perkins and Harding counties field; analysis No. 15062 (p. 100).

Mine.—Newcomb, an open-pit mine, in the SW. ¼ sec. 10, T. 20 N., R. 9 E., 5 miles southeast of Ralph and about 28 miles south of Reeder, N. Dak., on the Chicago, Milwaukee & St. Paul Railroad.

Lignite bed.—Designated the Widow Clark bed. Tertiary (?) age, Ludlow lignitic member of the Lance formation. It is the most important bed of lignite in that part of Harding County. Its average thickness in T. 20 N., R. 9 E., is about 4 feet, but it varies from 2 feet 8 inches in sec. 9 to 10 feet 10 inches in sec. 10. It is usually of good quality with very small amounts of impurities. It is tough and slightly woody, when freshly mined, but slacks readily upon exposure to air. It is used entirely for domestic purposes.

The bed was measured and sampled October 16, 1912, by J. B. Reeside, jr., as shown below:

Section of lignite bed in the Newcomb mine.

Laboratory No.	15062	
Roof, shale.	*Ft.*	*in.*
Lignite, dirty	[a] 0	6
Parting, shale	[a] 0	1
Lignite, dirty	[a] 0	1
Parting, shale	[a] 0	1
Lignite, fine quality	10	1
Floor, not stated.		
Thickness of bed	10	10
Thickness of lignite sampled	10	1

[a] Not included in sample.

Notes.—The lignite is mined by stripping, and the sample was collected from the face of the bed, which was somewhat weathered.

PERKINS COUNTY.

LODGEPOLE. NELSON MINE.

Sample.—Lignite; northwestern South Dakota field; analysis 14354 (p. 100).

Mine.—Nelson; 3 miles southwest of Lodgepole, and about 18 miles south of the Chicago, Milwaukee & St. Paul Railway, in sec. 29, T. 21 N., R. 12 E.

Lignite bed.—Tertiary age, Fort Union formation. Thickness of part sampled, 7 feet. Neither the top nor the bottom of the bed was exposed.

The sample was collected in the entry 140 feet northwest of the entry mouth, by E. R. Lloyd and E. G. Woodruff, on July 3, 1912.

STROOL. JONES MINE.

Sample.—Lignite; northwestern South Dakota field; analysis No. 12453 (p. 100).

Mine.—Jones; a drift mine 6 miles northwest of Strool, in sec. 35, T. 19 N., R. 10 E.

Lignite bed.—The lignite bed is of Tertiary(?) age, Lance formation, and showed the following section:

Section of lignite bed in Jones mine, 6 miles northwest of Strool.

Laboratory No.	12453	
Roof, sandy shale.	*Ft.*	*in.*
Lignite	[a]1	2
Shale, sandy	[a]0	½
Lignite	4	2
Floor, clay.		
Thickness of bed	5	4½
Thickness of lignite sampled	4	2

[a] Excluded from sample.

Note.—The lignite is brown and woody. Section and sample were taken at end of main entry by D. E. Winchester, July 22, 1911.

STROOL. KNUDSEN MINE.

Sample.—Lignite; northwestern South Dakota field; analysis No. 12454 (p. 100).

Mine.—Knudsen; a drift mine 5 miles southwest of Strool, in sec. 2, T. 17 N., R. 10 E.

Lignite bed.—The lignite bed is of Tertiary(?) age, Lance formation, and has the following section:

Section of lignite bed in the Knudsen mine.

Laboratory No.	12454	
Roof, shale.	*Ft.*	*in.*
Lignite	2	7
Shale, brown	[a]0	4
Lignite, bony	[a]0	7
Floor, clay.		
Thickness of bed	3	6
Thickness of lignite sampled	2	7

[a] Not included in sample.

The lignite is brown and woody. Section and sample were taken at end of second entry by D. E. Winchester on July 21, 1911.

STROOL. PHILLIPS MINE.

Sample.—Lignite; northwestern South Dakota field; analysis No. 12488 (p. 100).

Mine.—Phillips; a drift mine 5 miles south of Strool, in sec. 17, T. 17 N., R. 11 E.

Lignite bed.—The lignite is of Tertiary(?) age, Lance formation, and had a thickness of 2 feet 5 inches at the point of sampling. Both roof and floor are shale. The lignite is dark brown or black, has well-developed cleavage, and otherwise closely resembles the subbituminous coal of eastern Wyoming.

The bed was measured and sampled by D. E. Winchester on July 26, 1911. The sample was taken 150 feet from the mine mouth.

TENNESSEE.

ANDERSON COUNTY.

BRICEVILLE. CROSS MOUNTAIN NO. 1 MINE.

Sample.—Bituminous coal; Cumberland Plateau field; analyses Nos. 13237, 13238, 13264, 13265, and 13290 (p. 101).

Mine.—Cross Mountain No. 1, a drift mine one-half mile west of Briceville on a branch of the Southern Railroad.

Coal bed.—Known as the Coal Creek, but not correlated with other beds in eastern Tennessee. The coal is of Carboniferous (Pottsville) age, and the average thickness is 3 feet 10 inches, the range being from 3 feet to 4 feet 6 inches. It is rather hard coal and has a well-defined cleat. The roof is a hard sandy gray shale, called "slate" by the miners. Over the first 3,000 feet of entry this roof is poor, but after that it is very strong. The floor is an underclay which is usually rather hard but softens and swells when wet and when pillars are being pulled.

The coal bed was measured and sampled at three points in the mine during January, 1912, by J. J. Rutledge and E. B. Sutton, as described below:

Sections of coal bed in Cross Mountain No. 1 mine.

Section	A	B	C
Laboratory No.	13237	13238	13290
Roof, gray shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	0 7	.. ..	.. ..
Cannel coal	[a]0 1	.. ..	.. ..
Coal	3 0	3 10	4 0
Floor, underclay.			
Thickness of bed	3 8	3 10	4 0
Thickness of coal sampled	3 7	3 10	4 0

[a] Not included in sample.

Section A (sample 13237) was cut from the right rib of left entry 26, outby last break-through to the right.

Section B (sample 13238) was cut from a chain pillar on right entry 27, 18 feet outby the twelfth and last break-through.

Section C (sample 13290) was cut from the right rib of right entry 27, about 30 feet from main entry.

Sample 13264 was taken in room 3, off left entry 26.

Sample 13265 was taken in room 2, off left entry 26.

Notes.—In 1912 the Cross Mountain No. 1 mine was opened by a drift and worked by the room-and-pillar method. The coal was undercut by electric chain machines in the lower part of the bed. Very little explosive was used, as the coal frequently dropped while the head of the undercutting machine was being removed. When powder was necessary FFF black blasting powder was used exclusively, 40 per cent strength dynamite being used for brushing the roof. The coal was marketable either as steam or domestic coal, the latter quality being said to give the mine a decided advantage in the markets. The screens used were varied to suit the market.

BLEDSOE COUNTY.[a]

HERBERT. PROSPECT.

Sample.—Bituminous coal, Cumberland Plateau field; analysis No. 10915 (p. 101).

Mine.—Prospect on State land near Herbert post office, about 4 miles north of Saratoga Springs and about 14 miles northwest of Pikeville.

---

[a] For a description of the coals here listed see Bull. 9, Tennessee Geol. Survey.

Coal bed.—The coal is provisionally correlated with the Sewanee coal. Carboniferous system, Pennsylvanian series, Pottsville group, Walden sandstone formation. Roof, shale.

The bed was measured and sampled by H. G. Hart, under the direction of W. G. Phalen, on September 10, 1910. The sample represented a 6-foot 4-inch cut of coal. In another place the coal was 6 feet 4 inches thick, with a shale roof and clay floor. The base of the coal was not reached, but the thickness reported is 7 feet 4 inches.

The sample was taken near the mouth of the drift.

The relations of this coal bed are indicated by Phalen[a]. These descriptions include a consideration of the geologic position of the coal, together with notes on its physical and chemical character.

HERBERT. PROSPECT.

Sample.—Bituminous coal, Cumberland Plateau field; analysis No. 10916 (p, 101).

Mine.—Prospect on State land near Herbert post office, about 4 miles directly north of Saratoga Springs and 14 miles northwest of Pikeville, the county seat of Bledsoe County.

Coal bed.—The coal is provisionally correlated with the Sewanee coal, Carboniferous system, Pennsylvanian series, Pottsville group, Walden sandstone formation. Roof, shale; floor, clay.

The bed was measured and sampled on September 16, 1910, by H. G. Hart, under the direction of W. C. Phalen. The sample represented a 3-foot cut of coal. It was collected at the face of a new opening which had been driven about 10 feet.

Notes.—The prospect was not being worked at the time of collection.

LITTON. A. L. HALE MINE.

Sample.—Bituminous coal; Cumberland Plateau field; analysis No. 12584 (p. 101).

Mine.—A. L. Hale, a local mine 2 miles northwest of Litton, 15 miles northeast of Nashville, Chattanooga & St. Louis Railroad at Pikeville.

Coal bed.—Angel, Carboniferous age, Pottsville formation. Dip 20° southwest. Roof, sandstone; floor, clay.

The bed was measured and sampled by W. A. Nelson on August 31, 1911. The sample represented an 8-foot cut of coal.

LITTON. PROSPECT.

Sample.—Bituminous coal; Cumberland Plateau field; analysis No. 10803 (p. 101).

Mine.—Prospect at the head of Sequatchie Valley, 4 miles north of Litton and 12 miles northeast of Pikeville, the terminus of the Sequatchie Valley branch of the Nashville, Chattanooga & St. Louis Railroad.

Coal bed.—The position of the coal is 36 feet below the base of the Sewanee sandstone, Carboniferous system, Pennsylvanian series, Pottsville group, Lookout sandstone formation.

The bed was measured and sampled August 20, 1910, under the direction of W. C. Phalen. Eight feet of coal was measured.

The sample was collected 60 feet from the drift mouth in the main and only entry.

PIKEVILLE. J. W. MCFARLAND PROSPECT.

Sample.—Bituminous coal; Cumberland Plateau field; analysis No. 10731 (p. 101).

Mine.—J. W. McFarland prospect, 4 miles west of Pikeville, on the Cumberland Plateau.

---

[a] Phalen, W. C., Preliminary Report of the Coal Resources of the Pikeville Special Quadrangle of East Tennessee: Tenn. Geol. Survey Bull. 9, 1911, pp. 65-67.

Coal bed.—Morgan Springs. Carboniferous system, Pennsylvanian series, Pottsville group, Walden sandstone formation. Roof, soft blue clay, 18 inches thick.

The bed was measured and sampled August 3, 1910, under the direction of W. C. Phalen, in a country bank approximately 50 feet from the drift mouth. The sample represented a 21½-inch cut of coal.

Note.—This is the highest important coal in the Cumberland Plateau in this region.

PIKEVILLE. VAUGHN BROS. PROSPECT.

Sample.—Bituminous coal; Cumberland Plateau field; analysis No. 11049 (p. 101).

Mine.—Outcrop, about 10 miles west of Pikeville, on Cane Creek, above the junction of Cane and Meadow Creeks.

Coal bed.—The coal bed is provisionally correlated with the Sewanee coal. Carboniferous system, Pennsylvanian series, Pottsville group, Walden sandstone formation. Roof, shale; floor, clay.

The bed was measured and sampled by W. C. Phalen on October 10, 1910. The sample represented a 3-foot 9-inch cut of coal.

PIKEVILLE. VAUGHN BROS. PROSPECT.

Sample.—Bituminous coal; Cumberland Plateau field; analysis No. 11050 (p. 101).

Mine.—From an outcrop on Cane Creek, above the junction of Meadow and Cane Creeks. The outcrop is located about 10 miles west of Pikeville, the county seat of Bledsoe County.

Coal bed.—The coal bed is provisionally correlated with the Sewanee coal. Carboniferous system, Pennsylvanian series, Pottsville group, Walden sandstone formation.

The bed was measured and sampled by W. C. Phalen on October 10, 1910. The sample represented a 3-foot 2-inch cut of coal.

CUMBERLAND COUNTY.[a]

LITTON. J. H. HALE & SON PROSPECT.

Sample.—Bituminous coal; Cumberland Plateau field; analysis No. 10800 (p. 101).

Mine.—J. H. Hale & Son prospect. Head of Sequatchie Valley, 4 miles from Litton post office and 12 miles northeast of Pikeville, the terminus of the Nashville, Chattanooga & St. Louis Railroad.

Coal bed.—Sewanee (?) coal. Occurring in the shale and sandstone interval above the Sewanee sandstone. Carboniferous age, Pennsylvanian series, Pottsville group, Walden sandstone formation. Roof, shale.

The bed was measured and sampled by H. G. Hart, under the direction of W. C. Phalen, on August 20, 1910.

The sample was collected 30 feet from the mouth of the prospect and represented a 5-foot 6-inch cut of coal, which was underlain by 1 foot of bone.

LITTON. J. H. HALE & SON PROSPECT.

Sample.—Bituminous coal; Cumberland Plateau field; analysis No. 10802 (p. 101).

Mine.—J. H. Hale & Son prospect, head of Sequatchie Valley, 4 miles north of Litton and 12 miles northeast of Pikeville, the terminus of the Sequatchie Valley branch of the Nashville, Chattanooga & St. Louis Railroad.

Coal bed.—Morgan Springs. The highest important coal in this part of the Cumberland Plateau. Carboniferous age, Pennsylvanian series, Pottsville group, Walden sandstone formation. Roof, shale; floor, clay, underlain with sandstone.

The bed was measured and sampled August 20, 1910, under the direction of W. C. Phalen. The sample represented a 3-foot 6-inch cut of coal.

---

[a] For fuller descriptions of the coals here listed, see Bull. 9, Tennessee Geol. Survey, 1911.

RHEA COUNTY.[a]

DAYTON. NORTH POLE MINE.

Sample.—Bituminous coal; Cumberland Plateau field; analyses Nos. 10689, 10690, 10691, 10692, and 10693 (p. 102).

Mine.—North Pole, at Dayton.

Coal bed.—Richland. Carboniferous system, Pennsylvanian series, Pottsville group, Walden sandstone formation. The bed lies above the Sewanee sandstone (the lower conglomerate member). In some places the coal bed rests directly on it, though in other places a few feet of shale or clay intervene. Locally a few feet of bony coal or "rash" occur between the main coal and the conglomerate. Roof, shale; floor, bone or clay.

The bed was measured and sampled at five points by W. C. Phalen on July 30, 1910.

Sample 10689 was taken 3,000 feet from the mine mouth and represented a 25½-inch cut of coal. The lower 7 or 8 inches of coal are very soft; the rest is hard.

Sample 10690 was collected at the face of a room in left heading 5, about 2,600 feet from mine mouth, and represented a 23-inch cut of coal. Roof, shale; floor, clay.

Sample 10691 represents the bony coal or "rash" underneath the good coal in the room where sample 10640 was taken.

Sample 10692 was collected at the face of left heading 8, about 3,000 feet from the mouth of the mine and represented a 22-inch cut of coal, with bony or clay streaks. Roof, massive shale; floor, clay.

Sample 10693 was collected from the face of right heading 7, between 2,700 and 2,800 feet from the mine mouth, and represented a 24-inch cut of coal. Roof, shale; floor, clay.

Notes.—The so-called rash is a bony coal, and the sample was collected to prove this point and also to determine whether a use might be discovered for it. It is discarded in mining. It occurs locally between the coal and the top of the underlying conglomerate.

The coal is coked and the coke is used by the Dayton Coal & Iron Co. in the company's furnace at Dayton, on the Cincinnati, New Orleans & Texas Pacific Railroad.

DAYTON. NEW PROSPECT MINE.

Sample.—Bituminous coal; Cumberland Plateau field; analyses Nos. 10696, 10697, 10698, and 10699 (p. 102).

Mine.—New Prospect, at Dayton.

Coal bed.—Nelson. Carboniferous system, Pennsylvanian series, Pottsville group, Lookout sandstone formation.

The bed was measured and sampled by W. C. Phalan on July 29, 1910.

Sample 10696 was taken at the face of a room in left heading 3, about 1,200 feet from the mine mouth. The bed measured 3 feet 10½ inches. There was a 2½ layer of bone 8 inches from the top of the bed. The sample represents the lower 3 feet. Roof, sandstone; floor, bone, sometimes compact, underlain with clay and sandstone.

Sample 10697 was taken at the face of a room off left heading 2 and represented 2 feet 3 inches of coal. The lower 3 inches was laminated and soft coal. Roof, hard, sandy clay; floor, bone.

Sample 10698 was taken at the end of the right heading 2 and represented a 3-foot 2-inch cut of coal. Roof, dense, compact clay with stringers of coal varying in thickness from a knife's edge to 4 inches; floor, clay.

Sample 10699 was taken in the main heading, 1,500 to 1,600 feet from the mine mouth, and represented a 2-foot 5-inch to 2-foot 7-inch cut of coal, overlain by shale, coal, and clay. Floor, clay.

---

[a] For a fuller account of the coals here listed see Bull. 9, Tennessee Geol. Survey, 1911.

Notes.—This is the principal coal bed of the Lookout formation, and one of the most important in the southeastern part of the Pikeville Special quadrangle. The coal is coked and the coke is used by the Dayton Coal & Iron Co. in its furnace at Dayton. The daily output of the mine at the time of sampling was 150 tons.

UTAH.

CARBON COUNTY.

HIAWATHA. HIAWATHA NO. 1 AND NO. 2 MINES.

Sample.—Bituminous coal; Book Cliffs field; analyses Nos. 10904, 10905, 10907, and 10908 (p. 103).

Mine.—Hiawatha No. 1 and No. 2; drift mines at Hiawatha; railroad connections via Utah Southern Railway to Rio Grande & Western Railway at Price, 23 miles distant.

Coal bed.—Hiawatha. Cretaceous age, Mesaverde formation. Thickness, 15 feet. Dip, 1° southeast in No. 1 mine and 1° southwest in No. 2 mine. Roof, "draw slate" 18 inches thick, with sandstone cap above; floor, smooth, hard sandstone. The cover at points where samples were taken is 150 to 300 feet.

The bed was measured and sampled at four points in the mine by H. M. Wolflin, on September 9, 1910, as described below:

Sections of coal bed in Hiawatha No. 1 and No. 2 mines.

Section	A		B		C		D	
Laboratory No.	10904		10905		10907		10908	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Top coal	..	..	..	..	[a] 2	6	..	..
Coal, bony	..	..	..	..	[a] 0	5½	[a] 0	7½
Coal, clean	3	11	5	2	4	3	4	3
Coal, bony	0	1	0	1	0	½	[a] 0	4
Coal, clean	..	..	..	..	..	..	1	1
Coal, bony	..	..	..	..	..	..	0	½
Coal, clean	7	2	6	2	6	0	3	4½
Coal, bony	..	..	..	..	..	..	0	½
Coal, clean	..	..	..	..	..	..	..	10
Floor, sandstone.								
Thickness of bed	11	2	11	5	13	3	11	7
Thickness of coal sampled	11	2	11	5	10	3½	10	7½

[a] Not included in sample.

Section A (sample 10904) was measured at the face of room 7 off left entry 1, at a depth of 300 feet below the surface at No. 1 mine.

Section B (sample 10905) was measured at the face of left aircourse 2 at No. 1 mine.

Section C (sample 10907) was measured at the face of room 2 off dip entry 2 at No. 2 mine.

Section D (sample 10908) was measured at the face of room 1 off rise entry 2 at a depth of 150 feet below the surface at No. 2 mine.

Notes.—At the time of sampling the screening plant was equipped for producing ½, ⅝, 1¼, and 3-inch coal. No hand picking. There were 4 loading tracks with a capacity for 60 cars.

The mine was worked by the room-and-pillar system; in the rooms the coal was undercut and shot down with permissible explosives; some black powder was also used; in the entries the coal was shot from the solid; daily output 1,000 tons; coal acreage 3,260. A gravity incline connected the mines with the tipple 2 miles down the canyon. Mines began shipping coal in February, 1910.

PRICE. JESSE KNIGHT PROSPECT.

Sample.—Bituminous coal; Book Cliffs field; analysis No. 14678 (p. 103).

Mine.—Jesse Knight, a prospect in Right Fork of Deadman Canyon in SE. ¼ sec. 7, T. 13 S., R. 11 E., 9 miles northeast of Price, Utah, which is on the Denver & Rio Grande Railroad.

Coal bed.—No name. Cretaceous age, Mesaverde formation. This is the same bed from which sample No. 14801 was taken, and in this vicinity dips about 5° N.-NE.

The bed was measured and sampled on August 28, 1912, by F. R. Clark, as described below:

Section of coal bed in Jesse Knight prospect.

Laboratory No.	14678	
	Ft.	in.
Coal	1	2
Shale, sandy	[a]0	3
Coal	5	3
Thickness of bed	6	8
Thickness of coal sampled	6	5

[a] Not included in sample.

Notes.—The prospect was worked only during the winter season for local use. The coal is jet black, massive, with joint planes parallel to the strike of the beds. The sample was collected at a point 90 feet N. 70° W. from opening. The coal was slightly weathered.

SUNNYSIDE. NO. 1 MINE.

Sample.—Bituminous coking coal; Book Cliffs field; analysis No. 12632 (p. 103).

Mine.—No. 1; in NE. ¼ SE. ¼ sec. 32, T. 14 S., R. 14 E., at Sunnyside, which is reached by a branch of the Denver & Rio Grande Railroad.

Coal bed.—Lower. Cretaceous age, Mesaverde formation. Seven to 9 feet thick in this locality. Roof, "soapstone," said to be very weak and part of the coal is left for roof.

The bed was measured and sampled by F. R. Clark, September 14, 1911, at the face of the Fowler slope as described below:

Section of coal bed in No. 1 mine.

Laboratory No.	12632	
	Ft.	in.
Coal	1	6
Shale, soapstone	1	6
Coal	7	0
Thickness of bed	10	0
Thickness of coal sampled (at base of bed)	5	5

Notes.—Both beds (upper and lower veins) were being worked from this mine. The daily output at the time of sampling was about 1,600 tons. The coal was screened and loaded or sent to crushers to be crushed for the coke ovens with the coal from No. 3 mine.

SUNNYSIDE. NO. 3 MINE.

Sample.—Bituminous coking coal; Book Cliffs field; analyses Nos. 12546, 12630, and 12631 (p. 103).

Mine.—No. 3; in SW. ¼ SW. ¼ sec. 4, T. 15 S., R. 14 E., 1 mile southeast of Sunnyside, on branch of Denver & Rio Grande Railroad; connected with the railroad by the main haulage way through No. 2 mine.

Coal bed.—Cretaceous age, Mesaverde formation. Two beds are worked, the upper and lower, which, in the vicinity of the points sampled, are separated by only 6 feet of highly sandy shale forming a good roof in the one case and a good floor in the other. The lower bed is separated from a massive sandstone beneath by only a few inches of brown shale. The upper bed has a sandy shale roof containing in places a few fossil shells.

Three samples were collected from this mine (two from the upper and one from the lower bed) by F. R. Clark in 1911.

Sample 12546 was cut from the side of the outlet airway in NW. ¼ SW. ¼ sec. 9, T. 15 S., R. 14 E. The sample includes coal from the whole upper bed (6 feet 2 inches thick). The point from which sample was taken is 50 feet north-northwest from the surface opening and the coal was weathered more or less.

Sample 12630, also from the upper bed, was cut from the face of the second crosscut off right entry 1 off No. 1 rise, which is about 1¾ miles southeast from the mouth of the mine, and was fresh and unweathered. The coal is clean, black, and massive, free from partings, and was 4 feet 8 inches thick at the point sampled.

Sample 12631 from the lower bed was taken from "the dips," or entries down the dip from the main haulage way, in the mine. The bed was about 8 feet thick at this point (1¾ miles southeast from mouth of the mine), but only 6 feet 10 inches of the upper part of the bed was included in the sample.

Notes.—At the time of sampling the coal was undercut with hand picks and broken down with powder, and the output was about 900 tons daily. The greater part of the output was coked. No attempt was made to keep the coal from the two beds separate as they were so nearly alike in their tendencies to coke, as well as other physical and chemical characteristics. The coal from each bed was screened and loaded into cars or sent to the crusher to be crushed for the coke ovens.

SUNNYSIDE. PROSPECT.

Sample.—Bituminous coking coal; Books Cliffs field; analysis No. 12545 (p. 103).

Mine.—Prospect in NE. ¼ SW. ¼ sec. 5, T. 15 S., R. 14 E., three-fourths of a mile south of Sunnyside, Sunnyside district, on Sunnyside branch of the Denver & Rio Grande Railroad.

Coal bed.—Lower. Cretaceous age, Mesaverde formation. Dip, 7° N., 80° E. The bed was measured and sampled on July 30, 1911, by F. R. Clark, as shown below:

Section of coal bed in prospect three-fourths of a mile south of Sunnyside.

Laboratory No.	12545	
	Ft.	*in.*
Coal	[a] 2	8
Shale, sandy	[a] 2	2
Coal	[a] 3	0
Coal	6	0
Thickness of bed	13	10
Thickness of coal sampled	6	0

[a] Not included in sample.

The coal was more or less weathered.

The sample was taken at a point 85 feet N. 40° E. from mouth of slope.

SUNNYSIDE. PROSPECT.

Sample.—Bituminous coal; Book Cliffs field; analysis No. 12792 (p. 103).

Mine.—Prospect in the right fork of Rock Canyon in NE. ¼ SE. ¼ sec. 32, T. 13 S., R. 13 E., or 8½ miles northwest of Sunnyside.

Coal bed.—No name. Cretaceous age; Mesaverde formation. This coal appears first only about 3 miles southeast of the prospect. It is a lower coal than either of those mined at Sunnyside.

The bed was measured and sampled on October 25, 1911, by F. R. Clark. The coal was at this point 5 feet 7 inches thick, and a cut across the bed was included in the sample.

Notes.—The coal is black, massive, bright, and comparatively hard. The sample was somewhat weathered, as the cut was made only 200 feet N. 72° W. from the mine opening, and the face had been exposed to the atmosphere for a long time.

Sunnyside. Prospect.

Sample.—Bituminous coal; Book Cliffs field; analysis No. 14801 (p. 103).

Mine.—Prospect in the SE. ¼ NW. ¼ sec. 23, T. 13 S., R. 12 E., 14 miles northeast of Wellington, Utah, and 12 miles northwest of Sunnyside, Utah.

Coal bed.—Not named. Cretaceous age, Mesaverde formation. Dip about 5° N.-NW.

The bed was measured and sampled on September 29, 1912, by F. R. Clark, as shown below:

Section of coal bed in prospect 12 miles northwest of Sunnyside.

Laboratory No.	14801	
	Ft.	in.
Bone	[a]0	2
Shale, sandy	[a]0	1½
Coal	2	5
Bone	0	1½
Coal	5	8
Thickness of bed	8	6
Thickness of coal sampled	8	2½

[a] Not included in sample.

The sample was taken at a point 100 feet S. 40° E. from opening.

Notes.—The coal is black, hard, and massive, and aside from the bone parting is free from impurities. This is the lowest bed in the series at this point that has any considerable thickness.

The coal from the prospect was mined for local use during the winter season, but there was no railroad connection.

EMERY COUNTY.

Emery. Browning Mine.

Sample.—Bituminous coal; Emery field; analysis No. 12627 (p. 104).

Mine.—Browning; in the NE. ¼ SW. ¼ sec. 33, T. 22 S., R. 6 E., about 4 miles south of Emery.

Coal bed.—I. Cretaceous age, Ferron sandstone member of the Mancos formation. The bed at this place is 22 feet thick, which is the greatest thickness known in any coal bed in this field. Roof, brown shale; floor, brown shale.

The bed was measured and sampled by C. T. Lupton on September 19, 1911, as described below:

Section of coal bed in Browning mine.

Laboratory No.	12627	
Roof, brown shale.	Ft.	in.
Coal	[a]1	0
Shale, brown	[a]1	0
Coal with one or two 1-inch brown shale partings	[b]20	0
Floor, brown shale.		
Thickness of bed	22	0
Thickness of coal sampled	12	0

[a] Not included in sample.

[b] Upper 8 feet not included in sample.

The sample was taken at the back end of the main entry 165 feet N. 85° E. from pit mouth.

EMERY. CASPER MINE.

Sample.—Bituminous coal; Emery field; analysis 12652 (p. 104).

Mine.—Casper; in the SE. ¼ NW. ¼ sec. 26, T. 22 S., R. 6 E., about 4 miles southeast of Emery, in the Emery district.

Coal bed.—C. Cretaceous age, Ferron sandstone member of the Mancos formation. The bed averages about 9 feet thick in the immediate locality. Roof, sandstone; floor, soft drab clay.

The bed was measured by C. T. Lupton on September 23, 1911, as described below:

Section of coal bed in Casper mine.

Laboratory No.	12652	
Roof, sandstone.	*Ft.*	*in.*
Coal	[a]1	3
Sandstone and shale	[a]1	3½
Coal, very bony	[a]0	2
Coal, good	1	6
Coal, bony	1	1½
Coal	4	6
Floor, soft drab shale.		
Thickness of bed	9	10
Thickness of coal sampled	7	3½

[a] Not included in sample.

The sample was taken at the back end of the main entry about 200 feet northwest from the pit mouth.

EMERY. SURFACE PROSPECT.

Sample.—Bituminous coal; Emery field; analysis No. 14903 (p. 104).

Surface prospect.—Cave under rock ledge, in the SW. ¼ SW. ¼ sec. 32, T. 23 S., R. 6 E., about 12 miles southwest of Emery, in the Emery district.

Coal bed.—I. Cretaceous age, Ferron sandstone member of the Mancos formation. The bed is about 12 feet thick at this locality. Roof, drab and brown clay; floor, brown sandstone.

The bed was measured and sampled by C. T. Lupton on September 27, 1912, as described below:

Section of coal bed at surface prospect about 12 miles southwest of Emery.

Laboratory No.	14903	
Roof, drab and brown clay.	*Ft.*	*in.*
Coal	5	5
Clay, brown	[a]1	10
Coal	5	0
Floor, brown sandstone.		
Thickness of bed	12	3
Thickness of coal sampled	10	5

[a] Not included in sample.

The sample was taken from a surface prospect in a cave under a rock ledge at the place indicated above.

EMERY. WILLIAMS MINE.

Sample.—Bituminous coal; Emery field; analysis No. 12613 (p. 104).

Mine.—Williams; SE. ¼ SW. ¼ sec. 12, T. 22 S., R. 6 E.; about 2½ miles east of Emery.

Coal bed.—I. Cretaceous age, Ferron sandstone member of the Mancos formation. The bed averages about 6 feet thick in this part of the field. Roof, sandstone with a little coal in the lower part; floor, sandy shale. This coal bed is about 250 feet stratigraphically above the base of the Ferron sandstone member.

The bed was sampled and measured by C. T. Lupton on September 14, 1911, as described below:

Section of coal bed in Williams mine.

Laboratory No.	12613
Roof, sandstone.	*Ft. in.*
Coal	0 4½
Bone and coal	0 2
Coal	5 3
Floor, sandy shale.	
Thickness of bed	5 9½
Thickness of coal sampled	5 9½

The sample was taken at the back end of the main entry 200 feet S. 60° E. from the entry mouth.

SEVIER COUNTY.

EMERY. SURFACE PROSPECT.

Sample.—Bituminous coal; Emery field; analysis 15061 (p. 104).

Location.—Surface prospect; in the SW. ¼ NW. ¼ sec. 25, T. 24 S., R. 5 E., about 15 miles south of Emery.

Coal bed.—A. Cretaceous age, Ferron sandstone member of the Mancos formation. The bed averages 11 feet thick at this locality. Roof, sandstone; floor, brown shale.

The bed was measured by C. T. Lupton on November 2, 1912, as described below:

Section of coal at surface prospect, about 15 miles south of Emery.

Laboratory No.	15061
Roof, sandstone.	*Ft. in.*
Coal, bony	0 10
Coal, bright	1 7
Coal, dull	5 10
Bone	[a]0 3
Coal, bright	1 8
Coal, dull	1 1
Floor, brown shale.	
Thickness of bed	11 3
Thickness of coal sampled	11 0

[a] Not included in sample.

Sample 15061 was taken at a surface prospect at the locality stated.

FREMONT. HOGAN PROSPECT.

Sample.—Bituminous coal; Emery field; analysis No. 15090 (p. 104).

Prospect.—Hogan; about 15 miles northeast from Fremont, in the SW. ¼ NW. ¼ sec. 3, T. 26 S., R. 4 E.

Coal bed.—A. Cretaceous age, Ferron sandstone member of the Mancos formation. The bed at this place averages 5 feet thick. Roof, shale; floor, shale and bone.

The bed was measured and sampled by C. T. Lupton on October 21, 1912, as described below:

Section of coal bed in Hogan prospect.

Laboratory No.	15090
Roof, shale.	*Ft. in.*
Coal	[a]0 8
Bone	[a]0 5
Bone and bony coal	[a]1 0
Coal	3 0
Floor, shale and bone.	
Thickness of bed	5 1
Thickness of coal sampled	3 0

[a] Not included in sample.

The sample was taken at the back end of the drift, 20 feet N. 40° W. from the mouth.

SALINA. KEARNS & DUGGINS MINE.

Sample.—Bituminous coal; Wasatch Plateau field; analysis No. 15045 (p. 104).

Mine.—Kearns and Duggins; about 15 miles east of Salina, in the SW. ¼ SW. ¼ sec. 7, T. 22 S., R. 3 E., Salt Lake Meridian.

Coal bed.—"Duggins." Cretaceous age, Mesaverde formation. The bed averages 3 feet 9 inches thick at this locality. Roof, shale; floor, hard gray sandstone.

The bed was measured and sampled by C. T. Lupton on October 26, 1912, as described below:

Section of coal bed in Kearns & Duggins mine.

Laboratory No	15045
Roof, shale.	*Ft. in.*
Coal, containing resin globules	2 8
Bone	[a]0 2
Coal	0 11
Floor, gray sandstone.	
Thickness of bed	3 9
Thickness of coal sampled	3 7

[a] Not included in sample.

The sample was taken in a room off the entry, 178 feet north of the entry mouth.

SUMMIT COUNTY.

COALVILLE. REES-GRASS CREEK MINE.

Sample.—Subbituminous coal; Coalville field; analysis No. 13216 (p. 329).

Mine.—Rees-Grass Creek, a slope mine in SW. ¼ sec. 24, T. 3 N., R. 5 E., 5 miles northeast of Coalville.

Coal bed.—Wasatch. Cretaceous age, Frontier formation. The roof of the bed in some parts of the mine is sandstone and in others shale. The floor is shale.

The bed was measured and sampled by C. H. Wegemann on October 11, 1911.

The sample was taken 400 feet below the surface and 500 feet east of the main slope, and represented an 8-foot 6½-inch cut of coal.

Notes.—A slope is run on the dip of the bed about 30° northwest and the coal cars were brought to the surface by a hoisting engine. Capacity of mine, 150 to 200 tons.

COALVILLE. SUPERIOR MINE.

Sample.—Subbituminous coal; Coalville field; analysis No. 13217 (p. 329).

Mine.—Superior, a slope mine on the south side of sec. 16, T. 2 N., R. 5 E., 1 mile southeast of Coalville.

Coal bed.—Wasatch. Cretaceous age, Frontier formation. Dip of bed 10° to 15° to the south.

The bed was measured and sampled by C. H. Wegemann on October 11, 1911, and represented a 7-foot 6-inch cut of coal.

The sample was taken 200 feet below the surface, 1,000 feet northwest of the foot of slope.

Note.—Capacity of mine, 150 tons.

COALVILLE. WASATCH MINE.

Sample.—Subbituminous coal; Weber River field; analysis No. 13218 (p. 329).

Mine.—Wasatch, a slope mine in the SW. ¼ sec. 3, T. 2 N., R. 5 E., 3 miles northeast of Coalville.

Coal bed.—Wasatch. Cretaceous age, Frontier formation. Dip about 33° northwest, decreasing to 12° farther down the slope.

The bed was measured and sampled by C. H. Wegemann on October 11, 1911.

The sample was taken on the 800-foot level, 3,000 feet northeast of main slope, and represented a 10 foot 6-inch cut of coal.

Note.—The capacity of this mine at the time of sampling was about 500 tons.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 812–813.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 285.

UINTA COUNTY.

VERNAL. BLUE BELL MINE.

Sample.—Bituminous coal; Vernal field; analysis No. 10712 (p. 105).

Mine.—Blue Bell, a mine in sec. 8, T. 3 S., R. 22 E., about 7 miles north of Vernal and 100 miles east of Heber, which is the nearest station on the Rio Grande & Western Railway.

Coal bed.—No name. Cretaceous age, Mesaverde formation. Thickness, 7 feet 8 inches. Floor, brown carbonaceous shale.

The bed was measured and sampled by C. T. Lupton on August 3, 1910, as described below:

Section of coal bed in Blue Bell mine.

Laboratory No.	10712	
Roof, not stated.	*Ft.*	*in.*
Coal, bright and solid	1	4
Coal, bony	[a] 0	2½
Coal, bright and solid	0	4¾
Clay, brown, very hard	[a] 0	1
Clay, very soft	[a] 0	8
Coal, bright	0	9¾
Coal, dull	0	2
Coal, bright and solid	1	9
Shale, brown	[a] 0	3½
Coal, bright	2	0
Floor, shale.		
Thickness of bed	7	8½
Thickness of coal sampled	6	5½

[a] Not included in sample.

The above sample was taken at the face of the entry about 225 feet from the mouth.

VERNAL. GREEN MINE.

Sample.—Bituminous coal; Vernal field; analysis No. 10713 (p. 105).

Mine.—Green, a mine in sec. 13, T. 4 S., R. 22 E., 8 miles east of Vernal and about 110 miles east of Heber, which is the nearest station on the Rio Grande & Western Railway.

Coal bed.—No name. Cretaceous age, Mesaverde formation. Thickness, 4 feet 8½ inches. Roof, gray sandstone, about 2 feet thick; floor, gray sandstone about 8 feet thick.

The bed was measured and sampled by C. T. Lupton on August 2, 1910, as described below:

Section of coal bed in Green mine.

Laboratory No.	10713	
Roof, sandstone.	*Ft.*	*in.*
Coal, fair	0	5
Coal, soft, bony	[a] 0	5
Coal, hard, bony	[a] 0	4
Bone, streaked with coal	[a] 0	5½
Coal, good quality	0	9½
Coal, bony	0	½
Coal, good	0	7½
Shale and bone with thin coal streaks	[a] 0	4½
Coal, fair quality	0	7½
Coal, bony	[a] 0	3
Coal, sandy (considered as waste)	[a] 0	7
Floor, gray sandstone.		
Thickness of bed	4	11
Thickness of coal sampled	2	6

[a] Not included in sample.

The sample was taken at the face of the entry, 75 feet from the mouth. The coal at this point was slightly weathered.

VERNAL. REYNOLDS MINE.

Sample.—Bituminous coal; Vernal field; analysis No. 10812 (p. 105).

Mine.—Reynolds, a mine in sec. 20, T. 3 S., R. 19 E., about 20 miles west of Vernal and 80 miles east of Heber, which is the nearest station on the Rio Grande & Western Railway.

Coal bed.—Mancos. Cretaceous age, Mesaverde formation. Thickness, 5 feet 4 inches; dip, 20° south. Roof, shale, about 4 feet thick; floor, shale. Dip, 20° to the south.

The bed was measured and sampled by C. T. Lupton on August 18, 1910, as described below:

Section of coal bed in Reynolds mine.

Laboratory No	10812	
Roof, shale.	*Ft.*	*in.*
Clay shale with streaks of coal near bottom	[a] 0	7½
Coal, bright	[a] 0	2
Clay shale, brown and soft	[a] 0	2½
Coal, solid	2	1¼
Clay shale, brown with coal streaks	[a] 0	2
Coal, solid	0	6
Coal, bony	[a] 0	4
Coal, solid and bright	1	2¾
Floor, brown clay.		
Thickness of bed	5	4
Thickness of coal sampled	3	10

[a] Not included in sample.

The sample was taken at the face of the main entry about 210 feet from the surface.

WASATCH COUNTY.

HANNA. PROSPECT.

Sample.—Subbituminous coal; Blacktail Mountain field; analysis No. 10998 (p. 105).

Mine.—This prospect, in sec. 26, T. 1 S., R. 9 W., on Red Creek, is about 15 miles southwest of Hanna post office and 30 miles east of Heber, which is the nearest station on the Rio Grande & Western Railway.

Coal bed.—Cretaceous age, Mesaverde formation. Thickness, about 24 feet. Roof, a brown shale, which contains a small amount of bone and coal; floor, a brown clayey shale.

The bed was measured and sampled by C. T. Lupton on September 13, 1910, as described below:

Section of coal bed in prospect 15 miles southwest of Hanna.

Laboratory No	10998	
Roof, shale.	*Ft.*	*in.*
Coal, bright and hard	18	6
Shale, brown	[a] 0	1½
Coal, bright and hard	4	5
Coal, dull and slightly dirty	1	9
Floor, clay shale.		
Thickness of bed	24	9½
Thickness of coal sampled	24	8

[a] Not included in sample.

The above sample was taken at the face of the entry about 100 feet from the mine mouth.

HANNA. WINCHESTER PROSPECT.

Sample.—Lignite; Blacktail Mountain field; analysis No. 10997 (p. 105).

Mine.—Winchester, a prospect in sec. 7, T. 1 S., R. 7 W., on Farm Creek about 3 miles east of Hanna post office and 40 miles east of Heber, which is the nearest station on the Rio Grande & Western Railway.

Coal bed.—Mancos. Cretaceous age, Mesaverde formation. Thickness, about 5 feet.

The bed was examined and sampled by C. T. Lupton on September 9, 1910, as described below:

Section of coal bed in Winchester prospect.

Laboratory No	10997
Roof, gray sandstone.	*Ft.* *in.*
Coal, containing lenses of sandstone	[a]0 1
Coal, good and bright	4 10
Floor, carbonaceous shale.	
Thickness of bed	4 11
Thickness of coal sampled	4 10

[a] Not included in sample.

The above sample was taken about 10 feet down the slope from the entry mouth.

HEBER. CUMMINGS MINE.

Sample.—Subbituminous coal; Blacktail Mountain field; analysis No. 11058 (p. 105).

Mine.—Cummings; an abandoned mine in sec. 31, T. 1 S., R. 10 E., on Current Creek, about 28 miles southeast of Heber, which is the nearest station on the Rio Grande & Western Railway.

Coal bed.—Not named. Cretaceous age, Mesaverde formation. Thickness, about 13 feet.

The sample was taken by C. T. Lupton in September, 1910, and represented a 10-foot 6-inch cut of coal. The mine was more or less caved and the sample was taken from a good surface exposure.

VIRGINIA.

DICKENSON COUNTY.

CLINTWOOD. ELBERT POWERS MINE.

Sample.—Bituminous coal; central Appalachian field; analysis No. 14767 (p. 105).

Mine.—Elbert Powers, a local mine, 3 miles southeast of Clintwood.

Coal bed.—Supposed to be Clintwood. Carboniferous age, Pottsville formation. Roof, bone; floor, coal; cover, 25 feet.

The bed was measured and sampled by W. A. Nelson, September 17, 1912, as described below:

Section of coal bed in Elbert Powers mine.

Laboratory No	14767
Roof, not stated.	*Ft.* *in.*
Coal	[a]2 7½
Bone	[a]0 7
Coal	1 11
"Rash"	0 ¾
Coal	0 3½
"Rash"	0 ¾
Coal	2 4
Floor, coal.	
Thickness of bed	7 10½
Thickness of coal sampled	4 8

[a] Not included in sample.

The section was measured in the main entry 20 feet from the mine mouth.

CLINTWOOD. YEATES MINE.

Sample.—Bituminous coal; central Appalachian field; analysis No. 14766 (p. 105).

Mine.—Yeates, a local drift mine near Clintwood, 5 miles west of the Clinchfield, Carolina & Ohio Railroad.

Coal bed.—Clintwood. Carboniferous age, Pottsville formation. Thickness, uniform. The bed lies flat. Roof, shale; floor, shale.

The bed was measured and sampled by W. A. Nelson on September 21, 1912, as described below:

Section of coal bed in Yeates mine.

Laboratory No.	14766
Roof, shale.	*Ft.* *in.*
Bone	0 1
Coal	0 9
Bone	0 2
Coal	0 8½
Bone	0 1¼
Coal	0 3¾
Bone	0 1¼
Coal	0 3
Bone	0 1
Coal	1 8
Floor, shale.	
Thickness of bed	4 2¾
Thickness of coal sampled	4 2¾

The bed was measured at the end of right entry 1, off the main entry, 100 feet from the main entry.

HENRICO COUNTY.

GAYTON. CARBON HILL MINE.

Sample.—Semibituminous coal; Richmond basin field; analyses Nos. 15050 and 15051; also natural coke analysis No. 15052 (p. 106).

Mine.—Carbon Hill, a slope mine 1 mile from Gayton and connected by private railroad line to the Chesapeake & Ohio Railroad at Lorain.

Coal beds.—B and C. Triassic age, Newark series. The bed has an approximate dip of 35° to the west. Occasional faults are encountered. The B seam contains numerous bands of shale. The floor of the B bed is an underclay; the roof of the B bed and the roof and floor of the C bed are shale. The C bed has been coked in places by the heat of igneous intrusions.

The B bed was measured and sampled at one point and the C bed at two points in the mine by H. I. Smith on November 3, 1912, as described below:

Sections of C bed in the Carbon Hill mine.

Section	A	B
Laboratory No.	15050	15052
Roof, shale.	*Ft.* *in.*	*Ft.* *in.*
Natural coke	[a]0 2	2 3
Coal	3 4	[a]1 0
Floor, carbonaceous shale.		
Thickness of bed	3 6	3 3
Thickness of coal sampled	3 4	2 3

[a] Not included in sample.

Section of B bed in the Carbon Hill mine.

Laboratory No.	15051
Roof, "draw slate."	*Ft.* *in.*
Coal, hard	1 0
Shale	[a]0 1
Coal streaked with shale	0 6
Shale	0 ½
Coal, very friable	1 0
Shale	0 ½
Coal	0 11
Shale	[a]0 1
Coal	1 3
Floor, clay.	
Thickness of bed	4 11
Thickness of coal sampled	4 9

[a] Not included in sample.

Section A (sample 15050) was taken in the main gangway, opposite room 45 (C bed).

Section B (sample 15052) was taken in the main gangway, opposite room 32 (C bed).

Sample 15051 was measured at the face of right gangway 1 off slope 3, 20 feet ahead of room 21 (B bed).

Notes.—The Carbon Hill mine is opened by a slope which strikes the coal a short distance from the surface and follows the dip of the coal. At the time of sampling the coal was undercut by hand and shot down with a permissible explosive. The coal mined was washed on account of the "slate" partings in B bed being very brittle. It is estimated that one-fourth of the coal mined was lost in washing by breaking to a very fine slack. It was claimed that the mine had been worked at intervals for 100 years, and that it had a probable life of 100 years more. The future tonnage was to be derived from both pillar and advanced workings. Pillars had not, as yet, been pulled. The daily output of the mine was 150 tons, with a maximum day's run of 345 tons. This amount was to be increased to 600 tons. Pickers were employed on both the cars and on belt. The coal loaded was fine, containing practically no lump. There were two loading tracks with a capacity of 15 loaded cars and 15 empty cars. Only the B and C beds were being worked.

For a description of the geological relations of these coal beds, see 19th Annual Rept., 1897–98, U. S. Geol. Survey, 1899, p. 474.

RUSSELL COUNTY.

DANTE. NO. 2 AND NO. 5 MINES.

Sample.—Bituminous coal; Russell Fork field; analyses Nos. 10734, 10735, 10737, and 10738 (p. 106).

Mine.—Nos. 2 and 5, drift mines, 2 miles north of Dante on the Carolina, Clinchfield & Ohio Railway.

Coal bed.—Upper Banner. Carboniferous age, Norton formation. Average thickness, 5 feet 2¼ inches. Roof, gray shale, of good quality; floor, smooth hard shale.

The bed was measured and sampled at four points in the mine by P. M. Riefkin on August 13, 1910, as described below:

Sections of coal bed in No. 2 and No. 5 mines.

Section	A		B		C		D	
Laboratory No.	10734		10735		10737		10738	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, gray shale.								
Coal, hard	..	..	..	..	..	..	0	8
Coal	0	8¾	0	6¾	0	4½	1	2¼
Mother coal	..	..	..	..	..	..	0	¾
Coal, hard	0	3¼	0	5	0	3½	..	..
Coal	0	5¾	0	7	1	1½	0	4¾
Sandstone	ᵃ0	¾	ᵃ0	1½	ᵃ0	1½	ᵃ0	1½
Coal	1	4	1	4	0	10	0	4¼
Shale	ᵃ0	¾	ᵃ0	2¾	ᵃ0	½	ᵃ0	¾
Coal	0	5	0	6	0	5¼	0	6¾
Coal, hard	0	5	0	3¾	0	3¼	0	6¼
Coal	1	5¼	1	1	0	7	1	6
Mother coal	..	..	..	..	0	½	..	..
Coal	..	..	..	..	1	¾	..	..
Floor, hard smooth shale.								
Thickness of bed	5	2½	5	1¾	5	2¼	5	5¼
Thickness of coal sampled	5	1	4	9½	5	¼	5	3

ᵃ Not included in sample.

Section A (sample 10734) was measured at the face of the butt heading off the fourth left drift off the McClure entry, No. 2 mine.

Section B (sample 10735) was measured in room 16, off right heading 3, off the first drift off the McClure entry, No. 2 mine.

Section C (sample 10737) was measured at the face of room 14, right heading 5, off drift 9, No. 5 mine.

Section D (sample 10738) was measured from the butt on left heading 9, off drift 9, No. 5 mine.

Notes.—These mines are opened by drift entries and deliver the coal over the same tipple. At the time of sampling the coal was undercut by machines and shot down with black powder. A new tipple, under construction, was to be equipped to produce various commercial sizes. There was one loading track with a capacity of 40 cars. The combined daily production of the two mines was 1,600 to 1,700 tons, obtained from both advance and pillar workings. It was stated that the production of the mines would probably be increased to about 2,400 tons.

WISE COUNTY.

FLAT GAP. REUBEN BOLLING MINE.

Sample.—Bituminous coal; central Appalachian field; analysis No. 15174 (p. 107).

Mine.—Reuben Bolling. Local mine 2 miles east of Flat Gap and 10 miles from nearest railroad.

Coal bed.—Lower Bolling. Carboniferous age, Pottsville formation. Thickness, uniform, flat; roof, shale; floor, clay; cover, 25 feet.

The bed was measured and sampled by Charles Butts, November 1, 1912, as described below:

Section of coal bed in the Reuben Bolling mine.

Laboratory No.	15174	
Roof, shale.	*Ft.*	*in.*
Coal	[a]0	4
Clay	[a]0	10
Coal	1	5
Clay	0	1
Coal	1	5
Floor, clay.		
Thickness of bed	4	1
Thickness of coal sampled	2	11

[a] Not included in sample.

The bed was measured in the entry 15 feet from mine mouth.

GLAMORGAN. GLAMORGAN NO. 3 MINE.

Sample.—Bituminous coal; central Appalachian field; analysis Nos. 15100 and 15101 (p. 107).

Mine.—Glamorgan No. 3, a drift mine at Glamorgan, on the Wise Terminal Railroad.

Coal bed.—Glamorgan. Carboniferous age, Pottsville formation. Thickness, variable, nearly flat; roof, shale; floor, shale.

The bed was measured and sampled by Charles Butts, November 5, 1912, as described below:

Sections of coal bed in Glamorgan No. 3 mine.

Section	A		B	
Laboratory No.	15100		15101	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	9	3	8
Bone[a]	[a]0	1	[a]0	1
Coal	1	10	0	7
Bone[a]	[a]0	1½	..	..
Coal	0	8	..	..
Floor, not stated.				
Thickness of bed	4	5½	4	4
Thickness of coal sampled	4	3	4	3

[a] Not included in sample.

Section A (sample 15100) was measured at the face of the second dip entry, 6,000 feet from the mine mouth.

Section B (sample 15101) was measured at the face of the Glady entry, 7,000 feet from the mine mouth.

Note.—The coal from this mine is of good coking quality.

PARDEE. PARDEE MINE.

Sample.—Bituminous coal; central Appalachian field; analysis No. 15099 (p. 107.)

Mine.—Pardee; a drift mine at Pardee, on the Roaring Fork Railroad.

Coal bed.—Pardee (Limestone, Parsons). Carboniferous age, Pottsville formation. Thickness, uniform, flat; roof, shale; floor, shale.

The bed was measured and sampled by Charles Butts, November 6, 1912, and represented a 9-foot 7-inch cut of coal.

The section was measured at face of main entry, 2,000 feet from drift mouth.

Note.—The coal was hard.

WASHINGTON.[a]

KING COUNTY.

GRAND RIDGE. GRAND RIDGE MINE.

Sample.—Subbituminous coal; analyses Nos. 11736, 11737, 11738 (p. 107).

Mine.—Grand Ridge, a slope mine one-fourth mile east of Grand Ridge and 3 miles east of Issaquah, in the SE. ¼ NE. ¼, sec. 26, T. 24 N., R. 6 E., on the North Bend branch of the Northern Pacific Railway.

Coal beds.—No. 3, No. 4, and No. 7. Tertiary (Eocene) age, Puget formation. Dip, about 32° NW.

The beds were measured and sampled on February 9, 1911, by G. W. Evans, as described below:

Sections of coal beds in the Grand Ridge mine.

Section	A		B		C	
Laboratory No.	11736		11737		11738	
Roof: Section A, sandstone; section B, shale; section C, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	7	..	..	1	6
Shale, carbonaceous	[a]0	3	[a]0	4	..	..
Clay, white, plastic	[a]0	6	..	..	[a]0	½
Coal	1	11	3	1	1	5
Clay, white, plastic	[a]0	5	..	..	[a]0	½
Bone and coal	[a]1	2	..	..	..	..
Coal	..	..	..	..	1	7
Shale, laminated	[a]0	4	..	..	..	..
Clay, plastic	..	..	..	..	[a]0	5
Coal, somewhat bony	..	..	..	..	0	8
Clay, plastic	..	..	..	..	[a]0	5
Coal, impure	..	..	..	..	[a]0	6
Shale, carbonaceous	..	..	..	..	[a]1	1
Floor: Section A, sandstone; sections B and C, shale.						
Thickness of bed	6	2	3	5	7	7½
Thickness of coal sampled	3	6	3	1	5	2

[a] Not included in sample.

Section A (sample 11736) was collected from the No. 3 bed, on the left side of chute 4. The sample was dry when taken.

Section B (sample 11737) was collected from the No. 4 bed, on the north side where the rock tunnel cuts the bed. The sample was damp when taken.

Section C (sample 11738) was collected from bed No. 7. The sample was wet when taken.

Note.—The output from each of beds Nos. 3, 4, and 7 was 250 tons a day.

---

[a] For a detailed discussion of Washington coals see U. S. Geol. Survey Bull. 474.

KITTITAS COUNTY.

ELLENSBURG. BUCHANNON PROSPECT.

Sample.—Bituminous coal; Manastash field; analysis No. 13267 (p. 107.)

Locality.—Buchannon prospect, in sec. 16, T. 18 N., R. 15 E., about 25 miles west of Ellensburg, which is on the Northern Pacific and the Chicago, Milwaukee & Puget Sound Railways.

Coal beds.—No. 10d. Tertiary (Eocene) age, Manastash formation. Thickness, 3 feet 9½ inches.

The bed was measured and sampled by E. J. Saunders on August 2, 1911, as described below:

Section of coal bed in prospect, 25 miles west of Ellensburg.

Laboratory No.	13267	
	Ft.	*in.*
Bone and coal	0	3
Shale, crushed	[a]0	8
Coal and bone	0	5
Coal (lenses)	0	3½
Coal, soft, with shale	0	5
Coal	1	5
Coal, soft, with shale	0	4
Thickness of bed	3	9½
Thickness of coal sampled	3	1½

[a] Not included in sample.

The sample was collected from the face of the entry, 35 feet northeast of its mouth. The sample was wet when taken.

ELLENSBURG. PROSPECT.

Sample.—Bituminous coal; Manastash field; analysis No. 13266 (p. 107).

Locality.—Prospect in sec. 22, T. 18 N., R. 15 E., about 25 miles west of Ellensburg, which is on the Northern Pacific and the Chicago, Milwaukee & Puget Sound Railways.

Coal bed.—No. 7. Tertiary (Eocene) age, Manastash formation. Roof and floor, shale. Thickness, 2 feet 10½ inches.

The bed was measured and sampled by E. J. Saunders on August 1, 1911, as described below:

Section of coal bed in prospect, 25 miles west of Ellensburg.

Laboratory No.	13266	
Roof, shale	*Ft.*	*in.*
Coal, bony	0	8½
Coal	0	6
Bone	[a]0	1
Coal	1	4
Coal and bone (crushed)	0	3
Floor, shale.		
Thickness of bed	2	10½
Thickness of coal sampled	2	9½

[a] Not included in sample.

The sample was collected from face of the entry, 30 feet from the mouth. It was dry when taken.

Note.—The mine was idle at the time of sampling.

ELLENSBURG. PROSPECT.

Sample.—Bituminous coal; Manastash field; analysis No. 13268 (p. 107).

Locality.—Prospect in sec. 22, T. 18 N., R. 15 E., about 25 miles west of Ellensburg, which is on the Northern Pacific and the Chicago, Milwaukee & Puget Sound Railways.

Coal beds.—No. 9c. Tertiary (Eocene) age, Manastash formation.

The bed was measured and sampled by E. J. Saunders on August 1, 1911, as described below:

Section of coal bed in prospect, 25 miles west of Ellensburg.

Laboratory No.	13268	
	Ft.	*in.*
Roof, shale.		
Shale, carbonaceous	[a]0	2
Coal, slightly bony	0	6
Coal, soft, and shale	1	0
Coal	1	8
Shale, carbonaceous	[a]0	2
Floor, shale.		
Thickness of bed	3	6
Thickness of coal sampled	3	2

[a] Not included in sample.

The sample was collected from the face of the entry, 40 feet from its mouth. It was wet when taken.

ROSLYN. ROSLYN NO. 1 AND NO. 2 MINES.

Sample.—Bituminous coal; analyses Nos. 11522, 11523, 11524, 11525, and 11256 (p. 107).

Mines.—Roslyn No. 1 and No. 2, slope mines at Roslyn, in secs. 8 and 9, T. 20 N., R. 15 E., on a branch of the Northern Pacific Railway, with which line it connects at Clealum.

Coal bed.—Roslyn. Eocene age, Roslyn formation. Average thickness, 4 feet 4 inches; dip of bed in No. 1 mine, 9° W., and in No. 2,18° W.; roof, gray shale, 10 feet thick in Mine No. 1, and 18 to 20 feet thick in mine No. 2; floor in each mine, smooth, hard clay, in places more or less shaly; cover, at points where samples were taken, 30 to 120 feet thick.

The bed was measured and sampled at four points in the mine by H. M. Wolflin, on January 2, 1911, as described below:

Sections of coal bed in Roslyn No. 1 and No. 2 mines.

Section	A		B		C		D	
Laboratory No.	11522		11523		11524		11526	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, shale.								
Coal, soft	1	1½	1	1¼	1	1½	2	6
Coal, slaty	..	..	0	¼	..	..	..	..
Coal, hard	0	1½	..	..	0	¼	..	..
Coal, soft	0	9½	1	5	1	¼	..	..
Coal, sulphurous	0	1	[a]0	2	0	⅜	..	..
Coal, soft	0	6½	..	..	..	..	..	..
Coal, bony	0	½	..	..	..	..	0	2
Coal, soft	1	6	1	3	1	9	1	7
Floor, clay.								
Thickness of bed	4	2½	3	11½	3	11⅜	4	3
Thickness of coal sampled	4	2½	3	9½	3	11⅜	4	3

[a] Not included in sample.

Section A (sample 11522) was measured at the face of the southwest slant entry of the No. 1 mine, at a depth of 80 feet below the surface.

Section B (sample 11523) was measured at the face of east entry 1, in the No. 1 mine, 120 feet below the surface.

Section C (sample 11524) was measured at the face of west entry 2, in the No. 1 mine, 100 feet below the surface.

Section D (sample 11526) was measured at the face of the main slope of the No. 2 mine, 30 feet below the surface.

A composite sample was made by mixing samples 11522, 11523, and 11324. The results of an ultimate analysis of the sample are given under laboratory No. 11525.

Notes.—At the time of sampling none of the coal from these mines was shipped as run-of-mine. About 50 per cent of the coal passed through 2½ to 3 inch bar screens. The coal was not hand picked. There were three loading tracks, with a capacity for 30 or 40 cars. Each mine had its own tipple and screening plant. Each mine was opened by a slope; double entry, room-and-pillar system of mining used; black powder used for breaking coal after undercutting. The output of the No. 1 mine was 400 tons a day. The No. 2 mine was equipped for handling about 500 tons a day. Mine No. 1 had an unmined area of 400 to 500 acres and No. 2 of about 120 acres.

THORP. WILSON MINE.

Sample.—Bituminous coal; Manastash field; analysis No. 13269 (p. 108).

Mine.—J. Wilson, in sec. 33, T. 19 N., R. 16 E., 10 miles west of Thorp, a station on the Northern Pacific Railway.

Coal bed.—No name. Tertiary (Eocene) age, Manastash formation. The bed, including shale partings, is about 9 feet thick. Roof, gray shale; floor, carbonaceous shale.

The bed was measured by E. J. Saunders on July 17, 1911.

Section of coal bed in Joseph Wilson mine.

	Ft.	in.
Roof, gray shale.		
Shale, carbonaceous, slightly graphitic	1	2
Coal	0	3
Shale, carbonaceous, graphitic	0	9
Coal, impure and crushed	1	3
Shale, graphitic	0	11
Coal	1	0
Shale, carbonaceous	[a] 0	2
Coal	[a] 0	8
Shale, carbonaceous	[a] 0	4
Slate	[a] 1	0
Coal	[a] 1	8
Floor, carbonaceous shale.		
Thickness of bed	9	2

[a] Not mined.

The sample analyzed represented run-of-mine coal taken from bunkers. It was dry when collected.

LEWIS COUNTY.

MENDOTA. MENDOTA NO. 1 MINE.

Sample.—Subbituminous (cannel) coal; analyses Nos. 12305 and 14084 (p. 108).

Mine.—Mendota No. 1, a slope mine at Mendota, about 6 miles east of Centralia, on the Centralia and Eastern branch of the Northern Pacific Railway.

Coal bed.—Locally termed No. 3; Tertiary (Eocene) age, Puget formation. Dip 5 to 12 per cent. Thickness, approximately 10 feet with several partings of clay ½ to 1½ inches thick; roof, soft, moist, crumbly, massive sandstone; in most sections of the mine, between the coal and the roof there is a band of soft, moist, gray clay about 2 inches thick. The sandstone roof is about 6 to 12 feet thick and is overlain with hard gray shale. The floor consists of a fairly hard and smooth sandy clay.

The coal bed was sampled at two points in the mine by H. M. Wolflin on May 22, 1911, and May 31, 1912.

Sample 12305 represented selected coal cut from the rib on the second level. This coal had the appearance of cannel and occurs in lenses and as vertical streaks. The sample was cut from a vertical streak 1½ inches wide.

Sample 14084 was cut from rib, south level, and represented a selected sample of "cannel" coal that occurs in lenses in the coal bed. These lenses are irregular in size, shape, and occurence and consist of coal that is soft, easily lighted by a match, burns with a smoky flame, and gives off a strong odor of coal tar.

Notes.—The Mendota No. 1 mine was opened by a slope driven across the pitch at an angle of 35° to 40° to the direction of the dip. At the time of sampling the coal was shot off the solid with FFF black blasting powder. The shaker screens were 5 feet 4 inches by 10 feet with holes 3 by 6 inches and 2¼ inches in diameter. The shaker screens for the smaller sizes of coal were 5 feet 4 inches by 10 feet with ⅜-inch holes. The revolving screen for washed coal was 14 feet long—8 feet with ¼-inch openings and 6 feet with ⅞-inch openings. The sizes produced in washing were on ⅞-inch, on ¼-inch and through ¼-inch holes. Three loading tracks, with a capacity of 50 empty cars and 30 loaded cars, were available. The mine had a daily output of 300 tons with a maximum day's run of 800 tons. About 2,000 acres of coal remained to be taken out from this opening.

MORTON. PROSPECT.

Sample.—Subbituminous coal; analysis No. 12563 (p. 108).

Locality.—Prospect in the SW. ¼ sec. 12, T. 12 N., R. 4 E., 2 miles southeast of Morton, which is the southern terminus of the Tacoma Eastern Railroad.

Coal bed.—Edlund. Tertiary (Eocene) age, Manastash formation. Strike, S. 70° E.; dip 16° S., 20° W.; roof and floor, sandstone. The bed is reported to be 7 feet thick near the surface, but further in is much faulted and thins to 12 inches.

The bed was measured and sampled by A. J. Collier on August 18, 1911. The sample was taken 4 feet from the surface and represented 4 feet of coal.

Note.—At the time of sampling the prospect had been abandoned owing to faults and thinning out of the bed.

MORTON. PROSPECT.

Sample.—Subbituminous coal; analysis No. 12564 (p. 108).

Locality.—Prospect in the SW. ¼ sec. 6, T. 12 N., R. 5 E., 2 miles east of Morton, which is the southern terminus of the Tacoma Eastern Railroad.

Coal bed.—Not named. Tertiary (Eocene) age, Manastash formation. Dip at surface 22° NE., increasing with depth. Thickness reported to decrease from 6 feet to 2 feet with depth. Bed faulted at end of workings 350 feet from mouth of the tunnel.

The bed was measured and sampled by A. J. Collier on August 24, 1911, as described below:

Section of coal bed in prospect 2 miles east of Morton.

Laboratory No.	12564	
Roof, sandstone.	*Ft.*	*in.*
Coal	[a] 0	3
Bone	[a] 0	7
Coal	2	0
Floor, sandstone.		
Thickness of bed	2	10
Thickness of coal sampled	2	0

[a] Not included in sample.

The sample was collected in the drift 20 feet from the mouth.

Note.—The prospect had been abandoned owing to faults and thickness of bed.

MORTON. PROSPECT.

Sample.—Semianthracite coal; analysis No. 12565 (p. 108).

Locality.—Prospect in sec. 14, T. 13 N., R. 4 E., 4 miles north of Morton, which is the southern terminus of the Tacoma Eastern Railroad.

Coal bed.—No name. Tertiary (Eocene) age. Thickness, 12 to 15 feet.

The bed was measured and sampled by A. J. Collier on August 16, 1911, as described below:

Section of coal bed in prospect 4 miles north of Morton.

Laboratory No.	12565	
	Ft.	*in.*
Coal with thin sandstone partings	[a] 6+	0
Coal and bone	[a] 2	
Coal	6+	0
Thickness of bed	14+	0
Thickness of coal sampled	6+	0

[a] Not included in sample.

The sample was collected in the entry, about 60 feet from the mouth of the entry.

PIERCE COUNTY.

ASHFORD. PROSPECT.

Sample.—Semibituminous coal; analysis No. 12581 (p. 108).

Locality.—Prospect in the NW. ¼ sec. 15, T. 15 N., R. 6 E., at Ashford on the Tacoma Eastern Railway.

Coal bed.—Misqually Chief. Tertiary (Eocene) age, Puget formation. Roof, altered shale; thickness, 13 feet 4 inches.

The bed was measured and sampled by G. W. Evans on August 26, 1911, as described below:

Section of coal bed in prospect at Ashford.

Laboratory No.	12581	
Roof, altered shale.	*Ft.*	*in.*
Shale, carbonaceous	[a] 0	5
Coal	0	6
Sandstone	[a] 0	4
Coal	1	2
Shale	[a] 0	4
Coal	5	3
Bone	0	1
Coal and dirt	1	2
Coal	2	0
Shale	[a] 0	2
Coal	0	5
Shale	[a] 0	2
Coal, shaly	1	2
Clay, soft	[a] 0	2
Floor, not stated.		
Thickness of bed	13	4
Thickness of coal sampled	11	9

[a] Not included in sample.

The sample was collected in the entry 100 feet from its mouth. It was wet when taken.

FAIRFAX. PROSPECT.

Sample.—Bituminous coal; analysis No. 12478 (p. 108).

Locality.—Prospect in the SW. ¼ sec. 2, T. 17 N., R. 6 E., 2 miles south of Fairfax, which is on a branch line of the Northern Pacific Railway.

Coal bed.—Montezuma. Tertiary (Eocene) age, Puget formation. Roof and floor, strong carbonaceous shale.

The bed was measured and sampled by G. W. Evans on July 25, 1911, as described below:

Section of coal bed in a prospect 2 miles south of Fairfax.

Laboratory No.	[illegible]	
Roof, carbonaceous shale.	*Ft.*	*in.*
Shale, soft brown	[a]0	10
Coal, soft impure	[a]0	10
Coal, impure, varying in hardness	[a]3	11
Coal, good	4	0
Floor, carbonaceous shale.		
Thickness of bed	9	7
Thickness of coal sampled	4	0

[a] Not included in sample.

The sample was collected from the face of the entry, 45 feet from the mouth of the entry. It was wet when taken.

FAIRFAX. PROSPECT No. 1.

Sample.—Bituminous coal; analysis No. 12496 (p. 109).

Locality.—Prospect No. 1 in the NE. ¼ NW. ¼ sec. 34, T. 18 N., R. 6 E., one-half mile south of Fairfax, which is on a branch line of the Northern Pacific Railway.

Coal bed.—No. 1. Tertiary (Eocene) age, Puget formation.

The bed was measured and sampled by G. W. Evans on August 1, 1911, as described below:

Section of coal bed in Prospect No. 1.

Laboratory No.	12496	
Roof, shale.	*Ft.*	*in.*
Coal, impure	1	6
Coal	1	4
Shale, 8 inches thick.		
Shale and clay, 7 inches thick.		
Floor, sandy shale.		
Thickness of bed	2	10
Thickness of coal sampled	2	10

The sample was collected in the entry, 35 feet from its mouth. It was wet when taken.

FAIRFAX. PROSPECT No. 2.

Sample.—Bituminous coal; analysis No. 12495 (p. 109).

Locality.—Prospect No. 2 in the NE. ¼ NW. ¼ sec. 34, T. 18 N., R. 6 E., one-half mile south of Fairfax, which is on a branch line of the Northern Pacific Railway.

Coal bed.—No. 2. Tertiary (Eocene) age, Puget formation.

The bed was measured and sampled by G. W. Evans on August 1, 1911, as described below

Section of coal bed in Prospert No. 2.

Laboratory No.	12495	
Roof, shale.	*Ft.*	*in.*
Clay, soft dark	[a]0	4
Coal, dirty	2	0
Coal	0	11
Coal, bony	[a]1	2
Bone	1	0
Floor, sandy shale		
Thickness of bed	5	5
Thickness of coal sampled	3	11

[a] Not included in sample.

The sample collected was in the entry. 35 feet from its mouth. It was wet when taken.

WILKESON. GALE CREEK MINE.

Sample.—Bituminous coal; analyses Nos. W31921 to W31926, W32104 to W32108, 14390, W32145 to W32148, W32158 to W32161, and W32211 to W32214 (pp. 109, 110).

Mine.—Gale Creek, a drift and slope mine at Wilkeson, about 30 miles southeast of Tacoma, on a branch of the Northern Pacific Railway.

Coal bed.—Queen. Tertiary (Eocene) age, Puget group. Average thickness, 3 feet 8 inches; dip, 8° to 85° SW., with a probable average of about 30°. The cleat is indistinct and there are many faults and rolls throughout the bed. Roof, "draw slate" 5 inches thick, above which is a hard gray shale extending to a cap rock 30 to 40 feet above; floor, hard, smooth, gray clay, shaly in places.

The bed was measured and sampled at six points in the mine by H. M. Wolflin on June 18 and 25, 1912, and six other samples were taken in duplicate from 27 carloads, as described below:

Sections of coal bed in Gale Creek mine.

Section	A		B		C		D		E		F	
Laboratory No.	W31921 W31922		W31923 W31924		W31925 W31926		W32106		W32107		W32108	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
"Draw slate"	..	..	..	..	..	..	[a] 0	5	..	..	[a] 0	5
Coal	..	..	0	1	..	..	..	..	..	..	..	..
Bone (local)	..	..	0	½	..	..	[a] 0	1	..	..	..	..
Coal	1	11¾	2	¼	2	½	1	8½	2	2	2	1
Clay-streaked coal (?)	[a] 0	4½	[a] 0	4	[a] 0	3½	[a] 0	2	[a] 0	3½	[a] 0	6
Coal	1	4	1	2	1	5	1	4	1	2	1	8
Floor, shaly clay.												
Thickness of bed	3	8¼	3	7¾	3	9	3	8½	3	7½	4	8
Thickness of coal sampled	3	3¾	3	3¾	3	5½	3	½	3	4	3	9

[a] Not included in sample.

Section A (samples W31921 and W31922) was measured at the face of gangway 1, off new slope.

Section B (samples W31923 and W31924) was measured at breast 16 at the face of counter No. 1 north, off new slope.

Section C (samples W31925 and W31926) was measured on the pillar of breast 10, off north gangway 1, off new slope.

Section D (sample W32106) was measured in the air course of the new slope at No. 1 lift, below north gangway 1.

Section E (sample W32107) was a pillar sample, measured in the first crosscut, off breast 14, north gangway 1, off new slope.

Section F (sample W32108) was a face sample, measured in the crosscut on the new slope opposite south gangway 2.

A composite sample was made by mixing samples 31921 to 31926, inclusive, and 32106 to 32108, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14390.

Duplicate samples Nos. W32104 and W32105 were taken from four cars while being loaded at the mine.

Duplicate samples W32145 and W32146 were taken from four cars while being loaded at the mine.

Sample W32147 was taken from four cars while being loaded at the mine.

Duplicate samples W32158 and W32159 were taken from four cars while being loaded at the mine.

Duplicate samples W32160 and W32161 were taken from four cars while being loaded at the mine.

Duplicate samples W32211 and W32212 were taken from four cars while being loaded at the mine.

Duplicate samples W32213 and W32214 were taken from three cars while being loaded at the mine.

Coal that passed over the screens, constituting about 15 per cent of the total, was dumped into the cars, but no special note was made as to which cars were partly loaded with lump and which were loaded with the coal going through the 2½-inch screen. The screened coal passed through the washery before being loaded. The above car samples were obtained by taking about 50 pounds of coal from each car as it was being loaded. The 50-pound lots from three or four cars were then combined and the sample quartered down to laboratory size.

Notes.—The Gale Creek mine was opened by slopes and drifts, and the coal was mined by the breast-and-pillar method. All of the undercutting done was by hand; the larger part of the coal was shot off the solid with 30 per cent dynamite. In places the "draw slate" fell with the coal. The tipple was equipped with shaking screens 5 by 16 feet with 2½-inch holes. None of the coal was shipped as run-of-mine. Approximately 75 to 85 per cent of the coal passed through the screens; after having been screened it went to the washery. The oversize passed on to a picking belt, where it was carefully hand picked prior to being loaded on the car. The screenings were washed, but only one size was produced, although the plant was equipped for yielding two sizes. There was one loading track with a capacity for 12 empty and 15 loaded cars. The storage bins had a capacity for about 850 tons. There was 320 acres of coal land tributary to the various openings. The larger part of the coal was worked out down to the 400-foot level. One-half to three-fourths of the coal produced was from advance workings, the remainder being obtained from robbing the pillars. The mine had a daily production of 100 tons, with a maximum capacity of about 200 tons. Development work was under way and the capacity was to be increased to 250 to 300 tons a day.

For description and analyses of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 221, 899.

WEST VIRGINIA.

BRAXTON COUNTY.

Braxton. Braxton Mine.

Sample.—Bituminous coal; analysis No. 13556 (p. 110).

Mine.—Braxton; interior district; a mine at Braxton post office, on Coal & Coke Railway.

Coal bed.—Pittsburgh. Carboniferous age; Monongahela formation. Thickness, 4 to over 7 feet; average, nearly 7 feet. The roof is shale in most parts of the mine, but locally it is sandstone, in which case the coal is thinner than elsewhere. Bands of clay from a fraction of an inch to 3 or 4 feet thick cut across the bed in numerous places. Floor, shale.

The sample was collected about 325 feet southeast from the mouth of the mine by E. R. Lloyd, on March 18, 1912. The thickness of the bed where sampled was 5 feet 3 inches, clear coal, all of which was represented in the sample.

The output of the mine at the time of sampling was about two carloads per week.

BROOKE COUNTY.

Colliers. Lewis-Finley No. 1 Mine.

Sample.—Bituminous coal; analyses Nos. 15671, 15672 (p. 111).

Mine.—Lewis-Finley No. 1; Wheeling district; a drift mine, on the Pennsylvania Railroad.

Coal bed.—Pittsburgh. Carboniferous age; Monongahela formation. The bed has an average thickness of about 4½ feet and lies nearly flat. Roof, clay or bony coal.

The bed was measured and sampled at two places by D. D. Condit on January 6, 1913, as described below:

Sections of coal bed in Lewis-Finley No. 1 Mine.

Section	A		B	
Laboratory No.	15671		15672	
Roof, clay or bony coal.				
Coal unmeasured.				
Clay, averaging 10 inches.	*Ft.*	*in.*	*Ft.*	*in.*
Coal, bony	a0	7	..	..
Coal	1	10	2	3
Shale	a0	½	a0	½
Coal	a0	3¼	a0	3
Shale	a0	½	a0	1
Coal	0	11½	1	9½
Coal, bony	a0	½	..	..
Coal	0	8½	..	..
Coal, high in "sulphur"	a0	2	a0	3
Floor, clay.				
Thickness of bed	4	7¾	4	8
Thickness of coal sampled	3	6	4	½

a Not included in samples.

Section A (sample 15671) was measured in room 1, off butt entry 6, off the main entry.

Section B (sample 15672) was measured in room 77, off entry 10, side No. 2, 5,800 feet northwest of the mine mouth. Cover, 100 feet.

FAYETTE COUNTY.

CAPERTON. SEWELL MINE.

Sample.—Bituminous coal; New River field; analyses Nos. 14344, 14345, 14346, 14347, 14348, 14349, and 14350 (p. 111).

Mine.—Sewell; Kanawha-New River district; a drift mine at Caperton station, on the main line of the Chesapeake & Ohio Railway.

Coal bed.—Sewell. Carboniferous (Pottsville) age. Sewell formation. Average thickness, 3 feet 8 inches; dip, 1½ per cent northeast. The cleat is well marked, and there are no rolls or faults in this mine. The roof consists of a smooth "draw slate" 3 to 9 inches thick, above which is a sandstone cap. Floor, hard, smooth shale. Pieces of the roof occasionally mixed with the coal when loading, but none of the floor material was taken up with the coal. Cover at points of sampling, 250 to 400 feet.

The bed was measured and sampled at five points in the mine by G. H. Deike on July 11, 1912, as described below:

Sections of coal bed in Sewell Mine.

Section	A		B		C		D		E	
Laboratory No	14344		14345		14346		14348		14349	
Roof, sandy shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	9	0	6	0	11	0	6	0	10
Coal, gray	0	2½	0	1	0	3	0	3	0	1½
Coal	0	7	..	..	0	8½	0	6½	0	8½
Coal, gray	0	1½	..	..	0	1½	0	1½	0	1
Coal	1	6	1	10	2	0	1	7½	1	4½
Mother coal	0	½	..	..	..	..	0	½	0	½
Coal	0	9½	..	..	..	..	0	7½	0	9
Coal, bony	..	..	a0	4	a0	2½	..	..	a0	2
Floor, clay.										
Thickness of bed	4	0	2	9	4	2½	3	8½	4	1
Thickness of coal sampled	4	0	2	5	4	0	3	8½	3	11

a Not included in sample.

Section A (sample 14344) was measured at the face of a room turned off at the face of the drainage entry (Sugar Camp No. 3 workings).

Section B (sample 14345) was measured at the face of the last break-through in the third right air course (Sugar Camp No. 1 workings).

Section C (sample 14346) was measured at the face of the thirteenth right entry, 5,000 feet northeast of mine mouth. (Old Hill workings.)

Section D (sample 14348) was measured on pillar at the last room off cross entry 11. (Old Hill workings.)

Section E (sample 14349) was measured on the pillar of right entry 2. (Sugar Camp No. 2 workings.)

Two composite samples were made: (1) by mixing samples 14344, 14345, and 14346 for an ultimate analysis, the results of which are given under laboratory No. 14347; (2) by mixing samples 14348 and 14349 for an ultimate analysis, the results of which are given under laboratory No. 14350.

Notes.—The Sewell mine is opened by a number of drift entries, and the coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut both by hand and by electric chain machines and broken down with FFF black powder and permissible explosives. All of the coal was shipped as run-of-mine. There was a screening plant with 12-foot bar screens spaced 1¼ inches apart. The coal was clean and needed no picking when loading. There were 2 loading tracks with a capacity for 14 empty and 20 loaded cars. About 50 per cent of the coal was obtained from advance workings. There was approximately 300 acres of unmined coal tributary to the various entries. The output of the mine was 300 tons a day, with a maximum day's run of 550 days.

DUNLOOP. DUNN LOOP NO. 2 MINE.

Sample.—Semibituminous coal; New River field; analyses Nos. 14383, 14384, 14385, 14386, 14387, 14388, and 14389 (p. 111).

Mine.—Dunn Loop No. 2; Kanawha-New River district; at Dunloop, with railroad connections to the Chesapeake & Ohio Railway. Another road is under construction, the Glen Jean & Eastern, which will connect with the Virginian Railway. This will give an additional outlet for coal shipments.

Coal bed.—Sewell, Carboniferous (Pottsville) age, Sewell formation. Average thickness, 5 feet 6 inches; dip, 1½° northwest. Roof, "draw slate" 4 to 6 inches thick, above which is a stratum of soft gray shale. There is a sandstone cap rock 20 feet above the coal. Floor, smooth, hard fire clay, and shale. Cover at points of sampling, 75 to 200 feet.

The bed was measured and sampled at five points in the mine by J. J. Rutledge on July 10, 1912, as described below:

Sections of coal bed in Dunn Loop No. 2 mine.

Section	A		B		C		D		E	
Laboratory No	14383		14384		14385		14387		14388	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	9	2	7	2	6	2	2½	2	9
Cannel coal	0	½	0	3	0	3	0	2½	0	3
Coal	2	11	2	9	2	11	2	1	2	10
Shale	..	..	..	..	..	..	[a]0	1	..	..
Coal	..	..	..	..	..	..	0	7	..	..
Floor, fire clay, shale.										
Thickness of bed	5	8½	5	7	5	8	5	2	5	10
Thickness of sampled	5	8½	5	7	5	8	5	1	5	10

[a] Not included in sample.

Section A (sample 14383) was measured at the last break-through, to the right on the fifth main entry, 500 feet northeast of the mouth of the fifth main entry.

Section B (sample 14384) was measured at the face of room 20, off right entry 4, off the fourth main entry 1,600 feet southeast of the mouth of the fourth main entry.

Section C (sample 14385) was measured at the face of room 2, off the first left air course off the sixth main entry, 1,200 feet east of the mouth of the sixth main entry.

Section D (sample 14387) was measured at the face of room 5, off the air course of the third main entry, 500 feet southeast of the mouth of the third main entry.

Section E (sample 14388) was measured on pillar 17 on the sixth main entry, 1,040 feet southeast of the mouth of the sixth main entry.

Two composite samples were made: (1) by mixing samples 14383, 14384, and 14385 for an ultimate analysis, the results of which are shown under laboratory No. 14386; (2) by mixing samples 14387 and 14388 for an ultimate analysis, the results of which are shown under laboratory No. 14389.

Notes.—The Dunn Loop No. 2 mine is opened by six drift entries, and the coal from these various openings all goes to the same tipple. The coal is mined by the room-and-pillar system. At the time the mine was visited the coal was undercut by hand and shot down with FFF black blasting powder and permissible explosives. Thirty per cent dynamite was used for brushing the roof. The tipple was equipped with shaking screens with openings 5½ by 3½ inches and 2½ by 1¼ inches in size. Pickers were employed for picking the coal on a traveling belt. The daily production of the mine was 1,000 tons. The coal had a good appearance on the cars, the lumps being large but slightly broken by the loading system. There were 3 loading tracks, with a capacity for 29 empty and 32 loaded cars. All of the coal was shipped as run-of-mine. About 50 per cent of the coal was obtained from new workings and the remainder from the older parts of the mine.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 915–916.

ELVERTON. ELVERTON MINE.

Sample.—Semibituminous coal; New River field; analyses Nos. 14338, 14339, 14340, 14341, 14342, and 14343 (p. 112).

Mine.—Elverton; Kanawha-New River district; a drift mine, ¼ miile west of Elverton station on the main line of the Chesapeake & Ohio Railway.

Coal bed.—Carboniferous (Pottsville) age. Sewell formation. Average thickness, 4 feet; dip 1½ per cent northwest. Roof, heavy smooth shale above which there is a sandstone cap rock. The coal is practically free from regular partings or impurities. The floor consists of about 4 inches of bony coal, below which is a hard smooth shale. Cover, at points where the samples were taken, ranges from 100 to 400 feet.

The coal bed was measured and sampled at four points in the mine by G. H. Deike, July 10, 1912, as described below:

Sections of coal bed in Elverton mine.

Section	A		B		C		D	
Laboratory No	14338		14339		14341		14342	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, gray	..	..	..	..	0	1½	..	..
Coal	0	9	0	10	0	8½	0	10½
Coal, gray	0	1	0	1½	0	3	0	1½
Coal	0	7	0	7½	0	4½	0	10
Coal, gray	0	2	0	1	..	..	0	1
Mother coal	..	..	..	..	0	½	..	..
Coal	1	4	0	7	1	9½	1	0
Mother coal	..	..	..	..	0	¼	0	½
Coal	..	..	..	..	0	3¼	..	..
"Sulphur" band	..	..	0	⅛	0	⅛	..	..
Coal	..	..	0	6	0	7½	0	11
Mother coal	0	¼	0	¼	..	..	0	2
Coal	0	5½	0	5	..	..	0	7
Floor, bone and shale.								
Thickness of bed	3	4¾	3	2⅜	4	2⅝	4	7½
Thickness of coal sampled	3	4¾	3	2⅜	4	2⅝	4	7½

Section A (sample 14338) was measured at the face of the old Bayne entry, 3,900 feet southwest of No. 2 entrance.

Section B (sample 14339) was measured at the corner of the break-through, 10 feet from the face of the main entry, 3,900 feet southwest of No. 2 entrance.

Section C (sample 14341) was measured on pillar of room 2, left entry 1 off left entry 5, 3,100 feet south of No. 2 entrance.

Section D (sample 14342) was measured on the pillar of room 3, right entry 5, 3,100 feet southwest of No. 2 entrance.

Two composite samples were made: (1) by mixing samples 14338 and 14339 for an ultimate analysis, the results of which are shown under laboratory No. 14340; (2) by mixing samples 14341 and 14342 for an ultimate analysis, the results of which are shown under laboratory No. 14343.

Notes.—The Elverton mine is opened by a drift entry and the coal mined by the room-and-pillar system. At the time of sampling the coal was undercut both by hand and by electric chain machines and broken with FFF black powder. Dynamite was used for brushing the roof. The tipple was equipped with shaking screens 5 by 12 feet with openings 5 inches in diameter and also another set of screens 5 by 12 feet with openings 1¼ inches in diameter. About 50 per cent of the coal passed through the first set of screens. None of the coal was shipped as run-of-mine. Pickers were employed on the cars when loading coal. The screenings were used for making coke. The coal was very clean, the lumps large, and presented a good appearance on the cars. There were 3 loading tracks with a capacity for 30 empty and 40 loaded cars. There were also storage bins with a capacity for 400 tons of coal. There was about 700 acres of coal tributary to this mine. About one-half of the coal was derived from advance workings and the remainder from pillars. The production of the mine was 250 tons a day with a maximum day's run of 650 tons.

HAWKS NEST. MILL CREEK MINE.

Sample.—Semibituminous coal; New River field; analyses Nos. 14358, 14359, 14360, 14361, and 14362 (p. 112).

Mine.—Mill Creek; Kanawha-New River district; a drift mine about one-half mile north of Hawks Nest station on the main line of the Chesapeake & Ohio Railway.

Coal bed.—Sewell. Carboniferous (Pottsville) age, Sewell formation. Average thickness, 3 feet. The bed is practically horizontal. Roof, heavy shale and bony coal 6 to 18 inches thick, above which is a sandstone cap rock. Floor, hard smooth bony coal. Material from the roof and floor did not become mixed with the coal when mining. Cover, at the points where the samples were taken, approximately 600 feet.

The coal bed was measured and sampled at four points in the mine by H. I. Smith and G. H. Deike, July 12, 1912, as described below:

Sections of coal bed in Mill Creek mine.

Section	A		B		C		D	
Laboratory No.	14358		14359		14360		14361	
Roof, shale and bony coal.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Cannel coal	..	..	0	½	..	..	..	..
Coal	1	8	1	1	0	9	1	1½
Coal, gray	0	2¼	..	..	..	..	0	2
Coal	0	11	..	..	..	..	0	8
"Sulphur"	Streak.		Streak.		..	..	0	½
Coal, gray	..	..	0	2½	0	2	..	..
Coal	0	10¾	1	8	1	6½	0	8
Bone	0	½	..	..	..	..	..	..
Floor, bony coal.								
Thickness of bed	3	8½	3	0	2	5½	2	8
Thickness of coal sampled	3	8½	3	0	2	5½	2	8

Section A (sample 14358) was measured at the face of left entry 1 at room 49.

Section B (sample 14359) was measured at the face of left entry 2 at the neck of room 29.

Section C (sample 14360) was measured at the face of the third left air course.

Section D (sample 14361) was measured at the face of right entry 5.

A composite sample was made by mixing samples 14358, 14359, 14360, and 14361 for an ultimate analysis, the results of which are shown under laboratory No. 14362.

Notes.—The Mill Creek mine was opened by drift entries and the coal mined by the room-and-pillar system. At the time of sampling the coal was undercut by compressed-air punchers and broken down with a permissible explosive, which was also used for brushing the roof. None of the coal was shipped as run-of-mine. The screening plant consisted of bar screens 4½ by 12 feet with 3-inch spaces, through which about 50 per cent of the coal passed. The coal was clean and the lumps were large and presented a good appearance when loaded on the cars. There were two loading tracks with a capacity for 12 empty and 12 loaded cars. About two-thirds of the coal was obtained from advance work and the remainder from pillars. The daily output was 250 tons with a maximum day's run of 400 tons.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 924–925.

KAY MOOR. KAY MOOR NO. 1 AND NO. 2 MINES.

Sample.—Semibituminous coal; New River field; analyses Nos. 14294, 14295, 14296, 14297, 14298, 14299, 14401, 14402, 14403, and 14404 (p. 113).

Mine.—Kay Moor No. 1 and No. 2, Kanawha-New River district; three-fourths mile south of Kay Moor, on the south side of New River with railway connections to the Chesapeake & Ohio Railway. No. 2 mine is also on the south side of the river with railway connections to the Chesapeake & Ohio Railway at South Fayette.

Coal bed.—Carboniferous (Pottsville) age, Sewell formation. Average thickness about 3 feet 6 inches; slight dip to the west. Roof, smooth sandstone 18 inches thick; floor, rough, hard clay. Material from the floor or roof did not become mixed with the coal in mining.

The coal bed was measured and sampled at five points in No. 1 mine and at three points in No. 2 mine by H. I. Smith on July 10 and 11, 1912, as described below:

Sections of coal bed in Kay Moor No. 1 mine.

Section	A	B	C	D	E
Laboratory No	14294	14295	14296	14297	14299
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Cannel coal	.. ..	.. ..	0 3	.. ..	.. ..
Coal	0 11	0 11½	0 8	0 11	0 9
Coal, gray	0 4½	0 7½	0 7	0 8	0 7
Coal	1 1	1 6	1 3½	0 10	1 2
"Sulphur" band	Streak.	0 ⅛	Streak.	0 ½	Streak.
Coal	1 3	0 8	0 8	0 8½	0 9
Coal, bony	0 1	0 1½	0 1	0 1	0 1
Floor, clay.					
Thickness of bed	3 8½	3 10⅝	3 6½	3 3	3 4
Thickness of coal sampled	3 8½	3 10⅝	3 6½	3 3	3 4

Section A (sample 14294) was measured at the face of room 1, left entry 3, off main entry 3, at 4,700 feet south of the mine mouth.

Section B (sample 14295) was measured at the face of right entry 1½, off left entry 1, off Buffalo entry, 3,300 feet southeast of the mine mouth.

Section C (sample 14296) was measured at the face of left entry 1, off right entry 9, at 3,300 feet west of the mine mouth.

Section D (sample 14297) was measured at the face of west entry 11, 3,600 feet southwest of the mine mouth.

Section E (sample 14299) was measured on the pillar between rooms 3 and 4, off right entry 1, off main entry 7.

A composite sample was made by mixing samples 14294, 14295, 14296, and 14297. The results of an ultimate analysis of this sample are shown under laboratory No. 14298.

Sections of coal bed in Kay Moor No. 2 mine, south of Kay Moor.

Section	A	B	C
Laboratory No.	14401	14402	14403
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	3 0	0 9	0 9½
Coal, gray	.. ..	0 3	0 2
Coal	.. ..	1 10	1 3
"Sulphur" band	.. ..	.. ..	Streak.
Coal	.. ..	.. ..	0 9
Coal, bony	.. ..	0 1½	0 1
Floor, shale.			
Thickness of bed	3 0	2 11½	3 ½
Thickness of coal sampled	3 0	2 11½	3 ½

Section A (sample 14401) was measured at the face of left entry 3, off the main entry.

Section B (sample 14402) was measured at the face of room 9, off left entry 2.

Section C (sample 14403) was measured at the face of room 9, off left entry 1, at 150 feet from the entry.

A composite sample was made by mixing samples 14401, 14402, and 14403, for an ultimate analysis, the results of which are shown under laboratory No. 14404.

Notes.—Kay Moor No. 1 and No. 2 mines are opened by slope and the coal is mined by the room-and-pillar system. At the time the mines were visited the coal was undercut by air punchers and electric chain cutters and broken down with FFFF black blasting powder. None of the coal was shipped as run-of-mine. The screening plant had bar screens spaced 4 inches apart through which about 66 per cent of the coal passed, and also smaller bar screens with spaces 1½ inches wide which produced an egg coal. There were three loading tracks with a capacity for 16 empty and 16 loaded cars. There were storage bins with a capacity for 400 tons of screened coal and 600 tons of screenings. The screenings were not washed but were sent to the coking plant. About 10,000 acres of coal land was owned by the company, of which about 500 acres had been worked. The daily output of No. 1 mine was 550 tons, with a maximum day's run of 750 tons. The output of this mine will probably be increased to about 850 tons in the near future. Daily output of No. 2 mine, about 90 tons.

SOUTH NUTTAL. BROWN MINE.

Sample.—Semibituminous coal; New River field; analyses Nos. 10618, 10619, 10620, 10621, 10622, and 10623 (p. 113).

Mine.—Brown; Kanawha-New River district; a drift mine at South Nuttal on the Chesapeake & Ohio Railway.

Coal bed.—Sewell. Carboniferous (Pottsville) age, Sewell formation. Thickness, 3 to 4 feet; dip, 3° west; small faults; roof, blue shale 6 feet thick, strong and smooth; floor, hard smooth clay; cover 120 to 350 feet.

The bed was measured and sampled at five points in the mine by J. J. Rutledge on June 22, 1910, as described below:

Sections of coal bed in Brown mine.

Section	A	B	C	D	E
Laboratory No.	10618	10619	10620	10621	10622
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	0 8½	0 10½	0 10	0 10	.. 10
Coal, hard	0 1½	0 ⅛	0 1	0 1½	.. 1
Coal	2 0	2 11	2 6	2 6½	2 6½
Coal, bony	[a] 0 8	.. ..	.. ..	.. ..	.. ..
Floor, clay.					
Thickness of bed	3 6	3 9⅝	3 5	3 6	3 5½
Thickness of coal sampled	2 10	3 9⅝	3 5	3 6	3 5½

[a] Not included in sample.

Section A (sample 10618) was measured at the face of room 2 off Hill entry.

Section B (sample 10619) was measured on rib of Lockett heading, between rooms 1 and 2, about 2,000 feet from mouth of entry.

Section C (sample 10620) was measured at the neck of room 1 off right entry 6 off Wheeler entry.

Section D (sample 10621) was measured at the neck of room 4 off left entry 2 off entry 18.

Section E (sample 10622) was measured on the left rib near the face of entry 18.

A composite sample was made by mixing samples 10618 to 10622, inclusive; the results of an ultimate analysis of this sample are given under laboratory No. 10623.

Notes.—The coal is mined by the room-and-pillar and modified panel system; at the time of sampling FFF black blasting powder was used for breaking down the coal after undercutting with electric chain cutters. The coal was screened on 1¼-inch bar screens, and marketed as lump and screenings; pickers were employed on the cars when loading; there were two loading tracks with capacity for about 20 cars. Output 550 tons per day.

THAYER. EPHRAIMS CREEK (BUFFALO) MINE.

Sample.—Semibituminous coal; New River field; analysis No. 10629 (p. 114).

Mine.—Ephraims Creek (Buffalo); Kanawha-New River district; a drift mine at Thayer, on the Chesapeake & Ohio Railway.

Coal bed.—Fire Creek. Carboniferous age, Pottsville formation. Average thickness, 42 inches; dip, 3° west; roof, strong dark gray shale about 4 feet thick; floor, hard smooth gray shale; coal bed contains some cannel coal.

The bed was measured and sampled at one point in the mine by J. J. Rutledge, on June 20, 1910, as described below:

Section of coal bed in Ephraims Creek (Buffalo) mine.

Section	A	
Laboratory No	10629	
Roof, shale.	*Ft.*	*in.*
Coal	1	1
Cannel coal	0	5
Coal	2	0
Floor, clay.		
Thickness of bed	3	6
Thickness of coal sampled	3	6

This section (sample 10629) was measured at the face of room 5 off right entry 5 off the Slater entry.

Notes.—The mine is worked by the room-and-pillar system. At the time of sampling FFF black powder was used for breaking coal after undercutting with electric chain cutters. The coal was screened over 1¼-inch bar screens, and the screenings were passed over a ¾-inch screen. Pickers were employed on the car when loading; the capacity of the storage bins was 200 tons. There were two loading tracks. Practically all of the coal produced was from advanced workings. Daily output, 1,100 tons.

GREENBRIER COUNTY.

RICHWOOD. SPRUCE KNOB MINE.

Sample.—Bituminous coal; analysis No. 13547 (p. 114).

Mine.—Spruce Knob; Interior district on north fork of Cherry River, 9 miles southeast of Richwood, on a lumber road.

Coal bed.—Sewell (?). Carboniferous age, Pottsville formation.

The bed was measured and sampled in a room 1,500 feet southwest of the mine mouth, on March 15, 1912, by E. R. Lloyd. The section of the bed at the point of sampling was as follows:

Section of coal bed in Spruce Knob mine.

Laboratory No.	13547
Roof, shale.	*Ft. in.*
Coal, bony	[a]0 9
Coal, good, soft	4 1
Floor, shale.	
Thickness of bed	4 10
Thickness of coal sampled	4 1

[a] Not included in sample.

Notes.—The average thickness of the bed is 4 feet. At the time of sampling the average daily output of the mine was about 150 tons.

McDOWELL COUNTY.

ALGOMA. PINEY MINE.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14154, 14155, 14156, 14157, 14158, 14159, 14160, 14161, and 14162 (pp. 114, 115).

Mine.—Piney; Norfolk & Western district; a drift mine about 1 mile east of Algoma, with railroad connections to the Norfolk & Western Railway at Northfork.

Coal bed.—Pocahontas No. 3. Carboniferous (Pottsville) age, Pocahontas formation. Average thickness, 5 feet 3 inches; roof, 18 inches of "draw slate," above which is 6 inches of black shale with a sandstone cap rock. Floor, smooth hard shale. Material from the floor did not become mixed with the coal in mining, but occasionally some of the roof material fell with the coal.

The bed was measured and sampled at seven points in the mine by G. H. Deike, D. J. Price, and E. B. Sutton, June 22, 1912, as described below:

Sections of coal bed in Piney mine.

Section	A	B	C	D	E	F	G
Laboratory No.	14154	14155	14156	14158	14159	14160	14161
Roof, shale and sandstone.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	0 9½	1 6½	1 7	2 6	1 7	2 2	2 6
Coal, gray	0 2½	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
Coal	0 7	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
Bone	[a]0 3	[a]0 1½	[a]0 3	[a]0 3	[a]0 3	[a]0 3½	[a]0 3
Coal	4 3	3 7	3 8	3 10	3 8	3 10½	3 10
Floor, shale.							
Thickness of bed	6 1	5 3	5 6	6 7	5 6	6 4	6 7
Thickness of coal sampled	5 10	5 1½	5 3	6 4	5 3	6 ½	6 4

[a] Not included in sample.

Section A (sample 14154) was measured at the face of the main entry.

Section B (sample 14155) was measured at the face of room 14 off cross entry 10.

Section C (sample 14156) was measured at the face of room 30 off cross entry 8.

Section D (sample 14158) was measured on the pillar of room 15 off cross entry 5.

Section E (sample 14159) was measured on the rib of room 33 off cross entry 7.

Section F (sample 14160) was measured on the pillar of room 15 off cross entry 6.

Section G (sample 14161) was measured on the pillar of room 8 off cross entry 3.

A composite sample was made by mixing face samples 14154, 14155, and 14156. The results of an ultimate analysis of this sample are given under laboratory No. 14157. Another composite sample was made by mixing pillar samples 14158 to 14161, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14162.

Notes.—The Piney mine is opened by drift entries and the coal mined by the room-and-pillar system. At the time the mine was visited the coal was undercut by hand; FFF black powder was used for breaking the coal and a permissible explosive for brushing the roof. The screening plant was equipped with bar screens, 14 feet long, 3-inch spaces; also shaking screens 5 by 10 feet, with ¼ and ⅝-inch openings. About 65 per cent of the coal passed through the first screen. Pickers were employed on the car when loading coal. About 100 tons of screenings were coked per day. Daily output of mine, 1,000 tons. There were two loading tracks, with a capacity for 55 empty and 44 loaded cars. There were storage bins with a capacity for 800 tons. The coal was obtained from both advance and pillar work, and there was an ample acreage of coal for many years mining.

For analyses and descriptions of other samples of coal from this mine, see Bull. 22, Bureau of Mines, 1913, p. 966.

BIG FOUR. CIRRUS NO. 2 MINE.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14218, 14219, 14220, 14221, 14222, and 14223 (p. 115).

Mine.—Cirrus No. 2, Norfolk & Western district; a slope mine, at Big Four post office, on the Norfolk & Western Railway.

Coal bed.—Pocahontas No. 3 and Pocahontas No. 4. Carboniferous (Pottsville) age, Pocahontas formation. Average thickness 5 feet 5 inches; slight dip to south. The roof is a shale 3 to 4 feet thick, above which is a sandstone cap rock. The floor is a hard, rough fire clay. Material from the roof and floor did not become mixed with the coal in mining. Cover, at points of sampling, about 400 feet.

The bed was measured and sampled at five points in the mine by J. J. Rutledge and D. J. Price, on June 29, 1912, as described below:

Sections of coal beds in Cirrus No. 2 mine.

	No. 3 bed.				No. 4 bed.
Section	A	B	C	D	E
Laboratory No	14218	14219	14220	14221	14223
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	1 7½	2 ½	1 7½	1 9	1 8½
Coal, bony	[a]0 6½	[a]0 3	[a]0 5½	[a]0 5½	[a]0 3
Coal	.. ..	.. ..	.. ..	.. ..	1 1
Coal, bony	.. ..	.. ..	.. ..	.. ..	[a]0 2
Coal	3 5	3 2	3 7	3 0	1 5
Floor, fire clay.					
Thickness of bed	5 7	5 5½	5 8	5 2½	4 7½
Thickness of coal sampled	5 ½	5 2½	5 2½	4 9	4 2½

[a] Not included in sample.

Section A (sample 14218) was measured at the break-through near the face of the main heading, 2,850 feet south of the slope mouth.

Section B (sample 14219) was measured about 30 feet from the face of the sixth south entry, 1,500 feet southwest of the slope mouth.

Section C (sample 14220) was measured at the face of room 4, off the third south heading, 2,850 feet south of the slope mouth.

Section D (sample 14221) was measured at the face of the sixth east heading, 2,100 feet south of the slope mouth.

Section E (sample 14223) was measured at the face of the second north entry, 250 feet northwest of the slope mouth. This sample was taken in Pocahontas No. 4 bed, which is 4 feet 7½ inches thick.

A composite sample was made by mixing face samples 14218 to 14221, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14222.

Notes.—The mine is opened by a slope and the coal mined by the room-and-pillar system. At the time of sampling the coal was undercut by electric punchers and broken down with FFF black powder. There was no screening plant, all of the coal being shipped as run-of-mine. Pickers were employed on the cars in loading. There were two loading tracks with a capacity for 11 empty cars and 21 loaded cars for pit No. 3 and 9 empty cars and 7 loaded cars for pit No. 4. There was approximately 500 acres of unmined coal tributary to this slope. All of the coal mined was from advance workings. The daily output was about 400 tons.

HUGER. MIDDLE STATES MINE.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14416, 14417, 14418, 14419, 14421, 14422, and 14423 (p. 115).

Mine.—Middle States; Norfolk & Western district; a shaft mine at Huger station (Olmsted post office) 2 miles from Welch, on the main line of the Norfolk & Western Railway.

Coal bed.—Pocahontas No. 4. Carboniferous age, Pottsville formation. Average thickness about 5 feet. Roof, sandstone; floor, shale.

The bed was measured and sampled at seven points in the mine by E. B. Sutton and H. I. Smith, June 27, 1912, as described below:

Sections of coal bed in Middle States (Helena) mine.

Section	A		B		C		D		E		F		G	
Laboratory No.	14416		14417		14418		14419		14421		14422		14423	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	4½	0	1½	0	4½	1	10½	0	4½	0	1½	0	4
Bone	[a]0	1	[a]0	1	[a]0	1	0	½	[a]0	1½	[a]0	½	[a]0	1
Coal	1	11	1	11½	1	10½	2	0	1	8	0	2	1	8
Bone	[a]0	1	[a]0	1	[a]0	1	[a]0	½	0	½	0	¼	[a]0	½
Coal	1	8½	1	10	2	1	0	5	1	4	1	9	2	2
Bone	[a]0	1	[a]0	3	[a]0	2½	[a]0	1	..	..	[a]0	¾	[a]0	2
Coal, gray	..	..	..	..	..	..	..	..	0	2	..	..	..	..
Coal	0	10½	1	1	1	1	1	1	0	11	1	8	1	2
Coal, bony	..	..	..	..	..	..	..	..	..	..	0	1½	..	..
Coal	..	..	..	..	..	..	..	..	..	..	0	1½	..	..
Floor; shale.														
Thickness of bed	5	1½	5	5	5	9½	5	6½	4	7½	4	1	5	7½
Thickness of coal sampled	4	10½	5	0	5	5	•5	5	4	6	3	11¾	5	4

[a] Not included in sample.

Section A (sample 14416) was measured at the face of room 6 off the second rock heading.

Section B (sample 14417) was measured at the face of the second right air course.

Section C (sample 14418) was measured on the rib of the last break-through on the main diagonal entry.

Section D (sample 14419) was measured at the face of room 4 off first west parallel heading.

Section E (sample 14421) was measured on the pillar between rooms 3 and 6 off the north entry.

Section F (sample 14422) was measured on the pillar between rooms 8 and 9, left entry 4 off the main west heading.

Section G (sample 14423) was measured on the pillar between rooms 20 and 21, off second parallel entry off the main diagonal heading.

Two composite samples were made: (1) By mixing samples 14416 to 14419, inclusive, for an ultimate analysis, the results of which are shown under laboratory No. 14420; (2) by mixing samples 14421 to 14423, inclusive, for an ultimate analysis, the results of which are shown under laboratory No. 14424.

Notes.—The Middle States mine is opened by shaft 182 feet deep, and the coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by electric machines and shot down with permissible explosives. Dynamite was used for brushing the roof. All of the coal was shipped as run-of-mine. Pickers were employed on the car when loading. There were 2 loading tracks with a capacity for 70 empty and 30 loaded cars. Daily output, 1,000 tons. There was sufficient unmined coal to insure many years operation.

JED. HAVACO MINE.

Sample.—Semibituminous coking coal; Pocahontas field; analysis No. 13775 (p. 116).

Mine.—Havaco (formerly Jed); Norfolk & Western district; a shaft mine at Jed, on the Tug Fork branch of the Norfolk & Western Railway.

Coal bed.—Known as Pocahontas No. 3, Carboniferous (Pottsville) age, Pocahontas formation. The thickness is uniform and ranges from 4 feet 8 inches to 5 feet 4 inches, with an average of 5 feet. Dip, about 1½° to 2½° northwest. Roof, strong bedded sandstone underlain in parts with 12 to 15 inches of treacherous shale, which did not regularly fall with the coal, but was brushed in the entries. Floor, 12 to 18 inches of hard clay with smooth surface. Cover, about 400 feet.

The coal bed was measured and sampled at one point in the mine by J. W. Paul, April 5, 1912, as described below:

Sections of coal bed in Havaco (formerly Jed) mine.

Laboratory No.	13775	
Roof, dark shale.	*Ft.*	*in.*
Coal	0	5½
Mother coal	0	¼
Coal	0	6
Mother coal	0	½
Coal	0	10
Bone	[a]0	4
Coal	2	11
Floor, hard clay.		
Thickness of bed	5	1¼
Thickness of coal sampled	4	9¼

[a] Not included in sample.

Sample 13775 was measured at the face of first butt left entry.

Notes.—At the time of sampling the coal was undercut with chain machines in the bottom part of the seam and shot down with a permissible explosive. The tipple had no storage bins. The entire output was shipped as run-of-mine. There were three loading tracks with a capacity for 75 railroad cars.

For analyses and descriptions of other samples of coal from this mine, see Bureau of Mines Bull. 22, 1914, pp. 261, 993, 994.

JENKINJONES. POCAHONTAS NOS. 6, 6B, AND 7A MINES.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14185, 14186, 14187, 14188, 14189, and 14190 (p. 116.)

Mine.—Pocahontas Nos. 6, 6B, and 7A; Norfolk & Western district; drift mines; No. 6 mine is at Jenkinjones, on the Tug Fork branch ot the Norfolk & Western Railway, and No. 6B and No. 7A are one-half mile south of Jenkinjones.

Coal bed.—Pocahontas No. 3. Carboniferous (Pottsville) age, Pocahontas formation. Average thickness, 10 feet. Roof, dark shale, which is smooth and does not mix with the coal when mining. Floor, smooth hard shale, which does not adhere to the coal. Cover, approximately 300 feet.

The bed was measured and sampled at five points in the mine by J. J. Rutledge, G. H. Deike, and D. J. Price on June 26, 1912, as described below:

Sections of coal bed in Pocahontas Nos. 6, 6B, and 7A mines.

Section	A		B		C		D		E	
Laboratory No.	14185		14186		14187		14189		14190	
Roof, dark shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	6	2	8	2	10	3	3	3	0
Gray coal to sulphur	0	½	0	½	..	..	0	½	..	..
Coal	1	6	0	5	..	..	..	..	..	..
Mother coal	0	1	..	..	..	..	..	..	..	..
Coal, bony	..	..	[a]0	4½	[a]0	4½	..	..	[a]0	3½
Coal	0	9	0	5½	0	4	0	9	0	8½
Coal, bony	[a]0	3½	[a]0	2	[a]0	2½	0	1½	..	..
Coal	0	4	0	6	0	8	0	1½	..	..
Coal, gray	0	1	..	..	..	..	0	½	..	..
Coal, bony	..	..	[a]0	2½	[a]0	6	..	..	..	..
Coal	1	10	2	3½	1	5	0	2	..	..
Coal, bony	[a]0	3	[a]0	3	[a]0	½	[a]0	6	0	5
Coal	2	10	2	10	4	2	4	4	[a]3	5
Floor, light shale.										
Thickness of bed	9	6	10	2½	10	6½	9	4	7	10
Thickness of coal sampled	8	11½	9	2½	9	5	8	10	7	1½

[a] Not included in sample.

Section A (sample 14185) was measured at the face of the main heading of No. 6 mine, 250 feet west of the mine mouth.

Section B (sample 14186) was measured at the face of the aircourse of No. 6 mine, 250 feet from the mine mouth.

Section C (sample 14187) was measured at the face of the main heading of 6-B mine, 500 feet from the mine mouth.

Section D (sample 14189) was measured at the face of the first right cross heading of No. 6-B mine, 350 feet from the mine mouth.

Section E (sample 14190) was measured at the face of the main heading of Pocahontas No. 7-A mine, 120 feet from the mine mouth.

A composite sample was made by mixing face samples 14185, 14186, and 14187. An ultimate analysis of this sample is given under laboratory No. 14188.

Notes.—Both No. 6 and No. 7A mines are new and are opened by drift entries. The room-and-pillar system of mining is used. At the time of sampling the coal was undercut by electric machines and shot down with FFF black powder. The tipple was a temporary structure, the permanent plant being in course of construction. No. 6 mine had a daily output of 75 tons; No. 6B mine of 400 tons, and No. 7A was not shipping.

LECKIE. LECKIE NO. 1 AND NO. 2 MINES.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14271, 14272, 14273, 14274, 14275, 14276, 14277, 14278, 14279, 14280, 14281, and 14282 (pp. 116–117).

Mine.—Leckie No. 1 and No. 2; Norfolk & Western district; drift mines one-half mile east of Leckie on the Tug Fork branch of the Norfolk & Western Railway.

Coal bed.—Pocahontas No. 3. Carboniferous (Pottsville) age, Pocahontas formation. Average thickness, 7 feet 6 inches; dip, about 1½ per cent northwest. Roof, dark shale about 9 inches thick, above which is a strong cap rock; floor, hard, smooth clay. The material from the floor did not become mixed with the coal when mining, but a small amount of the shale from the roof fell with the coal. Cover, 150 to 200 feet.

The bed was measured and sampled at five points in the No. 1 mine by G. H. Deike on July 6, 1912, as described below:

Sections of coal bed in Leckie No. 1 mine.

Section	A		B		C		D		E	
Laboratory No.	14271		14272		14273		14274		14275	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	10	0	10	0	10	0	11	0	10
"Sulphur" band	[a] 0	¾	[a] 0	1	[a] 0	1	[a] 0	1	[a] 0	1½
Coal	1	10½	1	10	1	½	1	3½	1	5
Coal, gray	..	..	..	..	0	6	0	1	..	..
Mother coal	..	..	..	..	..	..	..	..	0	1
Coal	..	..	..	..	0	5	0	1	0	4
Coal, bony	[a] 0	3½	[a] 0	6	[a] 0	2	[a] 0	3½	[a] 0	4
Coal	1	6	2	2	..	..	1	11	1	5
Coal, gray	0	½	0	½	1	7	..	..	..	..
Coal	..	..	0	8	0	11	..	..	..	..
Coal, gray	..	..	0	2	0	4	0	1	..	..
Coal	3	7	1	0	..	..	..	..	..	..
Mother coal	..	..	0	½	..	..	..	..	0	1
Coal	..	..	0	9½	2	0	2	6	2	9
Floor, clay.										
Thickness of bed	8	2¼	8	1½	7	10½	7	3	7	4½
Thickness of coal sampled	7	10	7	6½	7	7½	6	10½	6	11½

[a] Not included in sample.

Section A (sample 14271) was measured at the face of room 1, off Monkey heading, 1,700 feet west of the mine mouth.

Section B (sample 14272) was measured at the face of Monkey heading, 1,900 feet west of the mine mouth.

Section C (sample 14273) was measured at the face of Kick-back heading, 1,250 feet northwest of the mine mouth.

Section D (sample 14274) was measured on a chain pillar of first right heading, 650 feet north of the mine mouth.

Section E (sample 14275) was measured on the pillar at the mouth of room 1, off second right heading, 950 feet northwest of the mine mouth.

A composite sample was made by mixing face samples 14271 to 14275, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14276.

The bed was measured and sampled at five points in the No. 2 mine by H. I. Smith on July 6, 1912, as described below:

Sections of coal bed in Leckie No. 2 mine.

Section	A		B		C		D		E	
Laboratory No.	14277		14278		14279		14280		14281	
Roof, "draw slate."	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Blocky coal	..	..	0	1	0	1	0	1	0	1
Coal	1	1	0	9	0	10	0	9	0	9½
"Sulphur" band	[a] 0	1	[b] 0	1	[b] 0	1	[b] 0	1	[b] 0	½
Coal	1	8	..	..	1	9	2	1	1	1
Coal, gray	..	..	0	3	..	..	..	..	0	4
Coal	..	..	1	6	..	..	..	..	0	6
Bone	[b] 0	5	[b] 0	3	[b] 0	5	[b] 0	4	[b] 0	6
Coal	4	6	1	6	1	8	1	8	1	10
Coal, gray	..	..	1	3	0	4	0	3	0	4
Coal	..	..	..	..	0	4	0	8	..	..
Coal, gray	..	..	..	..	..	..	0	4	..	..
Mother coal	..	..	..	..	0	1	......		..	..
Coal	..	..	1	10	2	5	1	8	2	10
Floor, clay.										
Thickness of bed	7	9	7	6	8	0	7	11	8	4
Thickness of coal sampled	7	4	7	2	7	6	7	6	7	9½

[a] Too brittle to exclude.

[b] Not included in sample.

Section A (sample 14277) was measured at the face of room 17 off the first right air course, 100 feet from the outcrop.

Section B (sample 14278) was measured at the working face.

Section C (sample 14279) was measured at the face of the main straight entry, 600 feet southeast of the mine mouth.

Section D (sample 14280) was measured at the face of room 5 off the diagonal entry.

Section E (sample 14281) was measured at the face of the first left entry, 1,300 feet from the mine mouth.

A composite sample was made from face samples 14277 to 14281, inclusive. The result of an ultimate analysis of this sample are given under laboratory No. 14282.

Notes.—The Leckie No. 1 and No. 2 mines are opened by drift entries and the coal mined by the room-and-pillar system. At the time the mines were visited electric chain machines were used in No. 1 mine for undercutting the coal and permissible explosives for breaking the coal. Daily output, 450 tons. About 30 per cent of the coal was obtained from advance workings. There was approximately 25 acres of unmined coal tributary to this entry. Coal-cutting machines were not used in No. 2 mine. Permissible explosives were used for breaking the coal. The capacity of No. 2 mine was 450 tons per day. A large part of the coal was obtained from advance workings. There was approximately 35 acres of coal tributary to this mine. All the coal from both mines was shipped as run-of-mine. Pickers were employed on the cars in loading. There was one loading track with a capacity for 20 empty and 30 loaded cars.

RODERFIELD. DAVY-POCAHONTAS NO. 1 AND NO. 2 MINES.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14262, 14263, 14264, 14266, 14267, and 14268 (p. 117).

Mine.—Davy-Pocahontas No. 1 and No. 2; Norfolk & Western district; drift mines. No. 1 mine is 1¾ miles and No. 2 mine 2 miles east of Roderfield on the Spice Creek branch of the Norfolk & Western Railway.

Coal bed.—No. 1 mine is in the War Creek bed. Carboniferous age, Pottsville formation. Average thickness of bed, 6 feet. The roof is sandstone, to which a small amount of coal adheres. Floor, sandstone. No. 2 mine is in the Davy bed, Carboniferous age, Pottsville formation. Average thickness of bed, 3 feet 6 inches. Roof, smooth sandstone; floor, black carbonaceous shale which is hard and smooth. Material from the floor occasionally becomes mixed with the coal in mining. Cover at No. 2 mine, 200 to 300 feet.

The coal bed in No. 1 mine was measured and sampled at three points in the mine by H. I. Smith on July 5, 1912, and the bed in No. 2 mine was measured and sampled at three points by G. H. Deike on July 5, 1912, as described below:

Sections of coal bed in Davy-Pocahontas No. 1 mine.

Section	A		B		C	
Laboratory No.	14266		14267		14268	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	9	1	1	0	3½
"Sulphur" band	..	..	..	..	[a]0	⅝
Coal	..	..	..	..	0	4
Coal, gray	0	5	0	5	0	4
Coal	0	8	0	6½	0	1
Mother coal and "sulphur"	0	¼	0	¼	0	¼
Coal	1	6¾	1	9	1	2
Mother coal and "sulphur"	..	..	..	..	0	⅝
Coal	..	..	..	..	0	7¾
Coal, bony	[a]0	5	[a]0	7	[a]0	5
Coal, very soft	0	1	..	..	..	..
Coal	1	11	2	3½	2	0
Coal, bony	[a]0	3	[a]0	2	[a]0	4
Floor, sandy shale.						
Thickness of bed	6	1	6	10¼	5	8¼
Thickness of coal sampled	5	5	6	1¼	4	10⅝

[a] Not included in sample.

Section A (sample 14266) was measured at the face of room 3, off entry 2.

Section B (sample 14267) was measured at the face of entry 2, opposite room 9

Section C (sample 14268) was measured at the face of entry 7, at the mouth of room 15.

A composite sample was made by mixing face samples 14266, 14267, and 14268. The results of an ultimate analysis of this sample are given under laboratory No. 14269.

Sections of coal bed in Davy-Pocahontas No. 2 mine.

Section	A		B		C	
Laboratory No.	14262		14263		14264	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	..	..	0	3	..	..
Mother coal	..	..	0	½	..	..
Coal	2	10½	0	11	1	1
Coal, gray	..	..	..	..	0	1
Mother coal	..	..	0	¾	..	..
Coal	..	..	0	3	0	4
Coal, gray	..	..	0	1	..	..
"Sulphur" band	..	..	..	..	[a] 0	⅜
Coal	..	..	0	7	1	2½
Shale, hard	[a] 0	2	[a] 0	1½	[a] 0	2
Coal	0	2	0	2	0	2
Shale, soft, block	[a] 0	6	[a] 0	6	[a] 0	6
Floor, sandy shale.						
Thickness of bed	3	8½	2	11¾	3	6⅞
Thickness of coal sampled	3	½	2	4¼	2	10½

[a] Not included in sample.

Section A (sample 14262) was measured at the face of room 5, left entry 1, 500 feet southwest of the mine mouth.

Section B (sample 14263) was measured at the face of the first left air course, 600 feet southwest of the mine mouth.

Section C (sample 14264) was measured at the face of the main heading, 600 feet west of the mine mouth.

A composite sample was made by mixing face samples 14262, 14263, and 14264. The results of an ultimate analysis of this sample are given under laboratory No. 14265.

Notes.—No. 1 mine is opened by a drift entry. The coal is mined by irregular tunneling intended for the room-and-pillar system. The mine is not well laid out. At the time of sampling coal cutters were not used. No. 2 mine was new; the main entry was about 600 feet long. At the time of sampling the work was largely development. Electric chain coal cutters were used for undercutting the coal. Black powder was used for breaking the coal in both mines and also for taking up the floor. All of the coal from No. 1 mine was shipped as run-of-mine. The coal from No. 2 mine was passed over bar screens with spaces 1¼ inches wide. Sixty per cent of the coal passed through this screen. Pickers were employed on the cars in loading. The coal on the cars was very clean; the lumps were large and had a good appearance. There were two loading tracks with a capacity for 20 empty and 20 loaded cars. Daily output of No. 1 mine, 150 tons; of No. 2 mine, 80 tons. There was approximately 1,000 acres of unmined coal tributary to these mines.

ROLFE. ROLFE MINE.

Sample.—Semibituminous coal, Pocahontas field; analyses Nos. 14394, 14395, 14396, 14397, 14398, and 14400 (p. 117).

Mine.—Rolfe; Norfolk & Western district; a drift mine at Rolfe on the North Fork branch of the Norfolk & Western Railway, 3 miles from North Fork.

Coal bed.—Pocahontas No. 3. Carboniferous age, Pottsville formation. Average thickness, about 5 feet 2 inches. The coal bed is practically horizontal. The roof consists of a "draw-slate" 2 inches thick, which falls with the coal; above the "draw-slate" is a hard smooth shale. The floor is a hard smooth shale which does not become mixed with the coal in mining. There is a streak of bony coal about 1 foot from the top of the bed, which is rather persistent throughout the mine. This is excluded in the sections given below.

The coal bed was measured and sampled at six points in the mine by E. B. Sutton and H. I. Smith, June 25, 1912, as described below:

Sections of coal bed in Rolfe mine.

Section	A		B		C		D		E		F	
Laboratory No.	14394		14395		14396		14397		14398		14400	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	3	1	4	1	4	1	2	1	1½	1	2
Bone	[a]0	4	[a]0	3	[a]0	4	[a]0	2	[a]0	2½	[a]0	2
Coal	1	1	1	1	1	1	1	1	1	2	1	0
Coal, gray	0	4	0	4	0	4	..	..	..	..	..	..
Coal, gray, bony	..	..	..	..	..	..	[a]0	4	[a]0	4	[a]0	4
Coal	2	3	2	1	2	1	2	3½	2	3½	2	2
Floor, shale.												
Thickness of bed	5	3	5	1	5	2	5	½	5	1½	4	10
Thickness of coal sampled	4	11	4	10	4	10	4	6½	4	7	4	4

[a] Not included in sample.

Section A (sample 14394) was measured at the face of B-2 butt entry off the B entry, 5,800 feet northwest of the mine mouth.

Section B (sample 14395) was measured at the face of B-1 butt entry off the B entry, 6,250 feet northwest of the mine mouth.

Section C (sample 14396) was measured at the face of the left boundary heading, 6,200 feet northwest of the mine mouth.

Section D (sample 14397) was measured at the face of room 15 off 3-A entry off right entry 1, 5,100 feet northeast of the mine mouth.

Section E (sample 14398) was measured at the face of room 18 off 2-A entry off right entry 2, 5,000 feet northeast of the mine mouth.

Section F (sample 14400) was measured on the pillar of room 4 off right entry 1, 4,200 feet east of the drift mouth.

A composite sample was made by mixing samples 14394 to 14398, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14399.

Notes.—The Rolfe mine is opened by drift entries and the coal mined by the room-and-pillar system. At the time the mine was visited the coal was undercut by electric chain cutters and broken down with FFFF black powder. FFF black powder was used for brushing the roof. All of the coal was shipped as run-of-mine and pickers were employed on the cars in loading. The lumps were fairly large, ranging from 6 to 12 inch cubes. There were two loading tracks with a capacity for 22 empty and 45 loaded cars. There were no storage bins. Daily output, 700 tons with a maximum day's run of 875 tons. All of the coal was from advance workings.

SUSANA. YUKON-POCAHONTAS.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14425, 14426, 14427, 14428, and 14429 (p. 118).

Mine.—Yukon-Pocahontas, Norfolk & Western district; a drift mine one-fourth mile west of Susana station (Yukon post office) on the Norfolk & Western Railway.

Coal bed.—War Creek. Carboniferous age, Pottsville formation. Average thickness, about 5 feet 3 inches. Dip, 1½ per cent to the northwest. Roof, shale; floor, bony coal 15 inches to 30 inches thick, underlain with sandstone.

The coal bed was measured and sampled at five points in the mine by H. I. Smith and E. B. Sutton, June 28, 1912, as described below:

Sections of coal bed in Yukon-Pocahontas mine.

Section	A		B		C		D		E	
Laboratory No.	14425		14426		14427		14428		14429	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal and mother coal	[a]0	1½	..	..	..	..	[a]0	2	[a]0	3½
Coal	..	..	0	1	..	..	..	..	..	..
Bone	..	..	[a]0	½	..	..	..	..	..	..
Coal	0	11½	0	9	1	1	..	..	2	2
"Sulphur" band	Streak.		Streak.		Streak.		..	..	0	½
Coal	3	4	1	10½	2	7	4	1	1	9
Bone	[a]1	4	[a]1	3½	[a]1	8½	[a]0	10	[a]1	0
Floor, sandstone.										
Thickness of bed	5	9	4	½	5	4½	5	1	5	3
Thickness of coal sampled	4	3½	2	8½	3	8	4	1	3	11½

[a] Not included in sample.

Section A (sample 14425) was measured on a pillar of the third right cross-cut off the main entry, at the last break-through, 1,200 feet northwest of the old opening.

Section B (sample 14426) was measured at the face of room 24 off the main air course, 1,700 feet southwest of the main opening.

Section C (sample 14427) was measured at the face of the main entry, 1,850 feet southwest of the main opening.

Section D (sample 14428) was measured at the face of room 7 off the main air course, 850 feet southwest of the main opening.

Section E (sample 14429) was measured at the face of room 14 off the main air course, 1,100 feet southwest of the main opening.

A composite sample was made by mixing face samples 14426 to 14429, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14430.

Notes.—The Yukon-Pocahontas mine is opened by drift entries and the coal mined by the room-and-pillar system. At the time the mine was visited all of the coal was mined by hand. FFF black blasting powder was used for breaking the coal. None of the coal was shipped as run-of-mine. The screening plant was equipped with screens for producing 4-inch, 1½-inch, and ⅜-inch coal. Pickers were employed on the car in loading and also at a traveling belt. The coal lumps were large and had a good appearance. There were four loading tracks with a capacity for 40 empty and 35 loaded cars. The mine had a daily output of 400 tons, practically all of which was from advance workings. The maximum capacity of the mine was about 575 tons per day. There was about 4,000 acres of unmined coal tributary to this mine.

MAYBEURY. NORFOLK MINE.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 11247 and 11780 (p. 119).

Mine.—Norfolk, a drift mine 2 miles from Maybeury, on the Norfolk & Western Railway.

Coal bed.—Pocahontas No. 3. Carboniferous (Pennsylvanian) age, Pocahontas formation. The bed is about 8½ feet thick and lies nearly horizontal.

Two car samples of coal from this mine were taken by E. R. Linkenhoker as the cars were being unloaded at the Bureau of Mines testing station at Pittsburgh, on November 28, 1910, and March 2, 1911, respectively.

Samples 11247 and 11780 each represent a car load of ¾-inch to 1½-inch nut coal.

For analyses and descriptions of other samples of coal from this mine, see Bureau of Mines Bull. 22, 1913, pp. 265, 1001.

WAR. JOHN'S BRANCH MINE.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14468, 14469, 14470, 14471, and 14472 (p. 119).

Mine.—John's Branch, Norfolk & Western district; a drift mine 1 mile south of War on the Dry Fork branch of the Norfolk & Western Railway.

Coal bed.—War Creek. Carboniferous age, Pottsville formation. Average thickness, 3 feet 10 inches. The coal bed is practically horizontal. Roof, 4 inches of "draw slate," which parts easily from the coal. Above the "draw slate" is a main cap rock. Floor, sandstone.

The coal bed was measured and sampled at four points in the mine by H. I. Smith and E. B. Sutton, June 29, 1912, as described below:

Sections of coal bed in John's Branch mine.

Section	A		B		C		D	
Laboratory No.	14468		14469		14470		14471	
Roof, "draw slate."	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	3½	0	3¼	..	..	..	..
Coal, gray	0	1	..	..	..	..	..	..
Coal, bony	..	..	0	¾	..	..	..	..
Coal	1	6	3	6	3	8	3	7
Mother coal and "sulphur"	0	½	..	..	..	..	..	..
Coal	0	10	..	..	..	..	..	..
Coal, bony	[a] 0	7	..	..	[a] 0	8	[a] 0	9
Floor, shale, coal, and sandstone.								
Thickness of bed	3	4	3	10	4	4	4	4
Thickness of coal sampled	2	9	3	10	3	8	3	7

[a] Not included in sample.

Section A (sample 14468) was measured at the face of the main entry, 800 feet from the mine mouth.

Section B (sample 14469) was measured at the face of heading 3 off the right entry.

Section C (sample 14470) was measured at the face of room 4 off the first left air course.

Section D (sample 14471) was measured at the face of the first right butt entry off left entry 2.

A composite sample was made by mixing face samples 14468 to 14471, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14472.

Notes.—The John's Branch mine is opened by drift entries and the coal mined by the room-and-pillar system. At the time of sampling all the mining was done by hand and the coal broken with FFF black powder. All of the coal was shipped as run-of-mine. There was no screening plant. Pickers were employed on the car in loading. The lumps of coal were large and had a good appearance. The loading tracks had a capacity of 15 empty and 15 loaded cars. Daily output, 125 tons.

WAR. WAR CREEK MINE.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14405, 14406, 14407, and 14408 (p. 119).

Mine.—War Creek, Norfolk & Western district; a drift mine at War, on the Dry Fork branch of the Norfolk & Western Railway.

Coal bed.—War Creek. Carboniferous age, Pottsville formation. Average thickness, 4 feet. Roof, smooth shale, 10 feet thick, which does not fall when the coal is mined. Floor, soft sandstone.

The coal bed was measured and sampled at three points in the mine by H. I. Smith and E. B. Sutton on June 30, 1912, as described below:

Sections of coal bed in War Creek mine.

Section	A	B	C
Laboratory No.	14405	14406	14407
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal, bony	0 8½	0 2½	.. ..
Coal	.. ..	0 8	.. ..
Mother coal and "sulphur"	.. ..	0 ½	.. ..
Coal	1 9½	1 1	.. ..
Mother coal and "sulphur"	0 ½	0 ½	.. ..
Coal	1 1	1 3	3 0
Coal, bony	0 1½	0 7½	.. ..
Floor, sandstone.			
Thickness of bed	3 4	3 11	3 0
Thickness of coal sampled	3 4	3 11	3 0

Section A (sample 14405) was measured at the face of the fourth left cross entry off the main entry.

Section B (sample 14406) was measured at the face of the main entry, 1,200 feet from the mine mouth.

Section C (sample 14407) was measured at the face of room 4 off the main air course, about 1,000 feet from the mine mouth.

A composite sample was made by mixing face samples 14405, 14406, and 14407. The results of an ultimate analysis of this sample are given under laboratory No. 14408.

Notes.—The War Creek mine is opened by drift entries and the coal mined by the room-and-pillar system. At the time of sampling the coal was undercut by hand and in some places was cut at the top of the bed. FFF black blasting powder was used both for breaking the coal and for brushing the roof. All of the coal was shipped as run-of-mine. Pickers were employed on the car in loading. The coal had a good appearance when loaded, the lumps being fairly large. There was one loading track with a capacity for a number of cars. Daily output, 50 tons. There was about 1,000 acres of land tributary to this mine. The War Creek mine is comparatively new.

WELCH. OREGON NO. 2 AND NO. 3 MINES.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14212, 14213, 14214, 14215, 14216, and 14217 (p. 120).

Mine.—Oregon No. 2 and No. 3; Norfolk & Western district; drift mines, 2 miles west of Welch, Hemphill Township, with railroad connections to the Norfolk & Western Railway.

Coal bed.—Pocahontas No. 4. Carboniferous age, Pottsville formation. Average thickness, 3 feet 6 inches; the bed is practically horizontal. The roof is a dark, hard, smooth, sandy shale, and does not fall immediately after the coal is taken out. Floor, hard, smooth sandstone. Material from the roof and from the floor does not become mixed with the coal when mined. Cover, 150 to 450 feet.

The coal bed was measured and sampled at five points in the mines by G. H. Deike on June 30, 1912, as described below:

Sections of coal bed in Oregon No. 2 and No. 3 mines.

Section	A	B	C	D	E
Laboratory No.	14212	14213	14214	14215	14216
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	0 11	1 0	1 0	0 10	1 0
Gray coal, hard	0 4	0 4	0 4	0 4	0 4
Coal	2 4	2 1	2 9	1 11	2 0
Floor, sandstone.					
Thickness of bed	3 7	3 5	4 1	3 1	3 4
Thickness of coal sampled	3 7	3 5	4 1	3 1	3 4

Section A (sample 14212) was measured at the face of main entry, 3,000 feet southwest of mouth of No. 3 mine.

Section B (sample 14213) was measured at the face of room 16 off fourth left entry, 2,000 feet south of mouth of No. 3 mine.

Section C (sample 14214) was measured on the pillar of room 1, off first left entry, 800 feet southeast of mouth of No. 3 mine.

Section D (sample 14215) was measured at the face of the main entry, 4,000 feet south of mouth of No. 2 mine.

Section E (sample 14216) was measured on the rib of room 11, off the air course, 100 feet from the face and 3,500 feet southeast of mouth of No. 2 mine.

A composite sample was made by mixing samples 14212 to 14216, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14217.

Notes.—The Oregon mines are opened by drift and worked by the room-and-pillar system of mining. At the time of sampling, the coal was undercut by compressed air punchers and shot down with FFF black powder. Permissible explosives were used for brushing the roof. The tipple was equipped with a shaking screen 5 by 24 feet with 3-inch holes. Fifty per cent of the coal passed through the screens. About 50 per cent of the coal was shipped as run-of-mine. The coal had a good appearance when loaded on the cars. There were two loading tracks with a capacity of 25 empty and 20 loaded cars. There was about 1,800 acres of unmined land tributary to this mine. Forty per cent of the coal was taken out in advance workings. The capacity of the mines was 450 tons a day with a maximum day's run of about 800 tons.

WELCH. STANDARD POCAHONTAS MINE.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 12512 and 12513 (p. 120).

Mine.—Standard Pocahontas; Norfolk & Western district; the mine is opened by a shaft 370 feet deep and is 2 miles west of Welch on the Norfolk & Western Railway.

Coal bed.—Pocahontas No. 3 bed. Carboniferous age, Pocahontas formation. Thickness, 4 feet 7 inches to 6 feet. There is a characteristic bone parting 2 to 5 inches thick near the middle of the bed. Roof, "draw slate," overlain by 3 feet of black shale. Particles of the roof did not mix with the coal in loading. Floor, hard, smooth, sandy clay. Cover, about 375 feet.

The coal bed was measured and sampled at two points in the mine by J. T. Ryan on August 8, 1911, as described below:

Sections of coal bed in Standard Pocahontas mine.

Section	A		B	
Laboratory No.	12512		12513	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*
Coal laminated with mother coal	0	6¼	0	3½
"Sulphur"	0	⅛	..	..
Coal	0	9⅝	1	1¼
Bone	[a] 0	4	[a] 0	2¼
Coal	0	3¼	..	..
Mother coal	0	1	..	..
Coal	2	10	3	4
Shale	0	¼	..	..
Coal	0	1½	..	..
Floor, sandy clay.				
Thickness of bed	5	⅜	4	11
Thickness of coal sampled	4	8⅜	4	8¾

[a] Not included in sample.

Section A (sample 12512) was measured at the face of the main entry in No. 2 shaft, 85 feet from the bottom of the shaft.

Section B (sample 12513) was measured at the face of entry driven from No. 1 shaft to connect with No. 2 shaft, about 120 feet from the bottom of No. 1 shaft.

Notes.—At the time of sampling the coal was undercut by puncher machines and blasted down with permissible explosives. The machine cuttings were loaded out with the coal. The entire future output of the mine will be from advanced work as this is a new development.

MARION COUNTY.

MONONGAH. MINE NO. 63.

Sample.—Bituminous coal; analyses Nos. 11429, 11430, 11431, and 11432 (p. 121).

Mine.—No. 63 (formerly No. 8) Monongahela district; a slope mine at Monongah, on the main line of the Baltimore and Ohio Railroad.

Coal bed.—Pittsburgh. Carboniferous age, Monongahela formation; average thickness 7 feet; dip about 3° northwest; roof, dark shale 2 to 8 feet thick with sandstone cap rock; floor, fire clay; cover at points of sampling, 200 to 400 feet.

The bed was measured and sampled at four points in the mine by J. J. Rutledge on December 19, 1910, as described below:

Sections of coal bed in No. 63 mine, at Monongah.

Section	A		B		C		D	
Laboratory No.	11429		11430		11431		11432	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	0	1	11	1	7	1	10¾
"Sulphur" band	..	..	0	¼	[a]0	½	0	¼
Coal	..	..	0	4½	..	..	0	4½
Coal, bony	[a]0	½	[a]0	1	..	..	[a]0	1
Coal	0	3¼	0	4	..	..	0	4
Coal, bony	[a]0	¼	[a]0	¼	..	..	0	¼
Coal	0	3	0	4	1	5	0	4
Coal, bony	[a]0	1	[a]0	1	[a]0	1½	[a]0	1
Coal	2	3	2	10	3	10	2	10
"Sulphur" band	[a]0	½	[a]0	½	..	..	0	¼
Coal	0	6	..	..	..	..	1	5¼
"Sulphur" band	0	¼	..	..	..	..	..	..
Coal	1	6	1	7¼	..	..	..	..
Floor, clay.								
Thickness of bed	7	¾	7	7¾	7	0	7	5¼
Thickness of coal sampled	6	9½	7	5	6	10	7	3¼

[a] Not included in sample.

Section A (sample 11429) was measured at the face of room 14, off left entry 3 off north entry 2, about 2,700 feet northwest of the mouth of the main slope.

Section B (sample 11430) was measured at the face of room 14 off left entry 4 off north entry 2, about 3,200 feet northwest of the mouth of the main slope.

Section C (sample 11431) was measured at the face of room 18 off left entry 2 off north entry 2, about 2,650 feet from the mouth of the main slope.

Section D (sample 11432) was measured at the face of room 30 off left entry 1, off north entry 2, about 2,900 feet northwest from the mouth of the main slope.

A composite sample was made by mixing face samples 11429 to 11432, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 11433.

Notes.—Coal hard and blocky and used largely for firing locomotives, by-products and lake shipments; some coke was made from the screenings at the mine. There were three loading tracks with capacity for 60 to 75 cars. The coal was mined by the room-and-pillar system with modified panel system; permissible explosives were used exclusively; the coal was undercut with electric chain machines; daily output, 800 to 1,000 tons.

MONTANA STATION. PARKER RUN MINE.

Sample.—Bituminous coal; analyses Nos. 15067, 15068, 15069, 15070, 15071, and 15072 (p. 121).

Mine.—Parker Run; Monongahela district; a drift mine one-fourth of a mile north of Montana station on the Baltimore & Ohio Railroad.

Coal bed.—Known as the Sewickley. Carboniferous age, Monongahela formation. Thickness, 5 feet 6 inches to 6 feet; average, 5 feet 9 inches. The character of the seam is fairly regular, though there are some sulphur balls and occasional clay binders. Roof, smooth sandstone; floor, soft fire clay; particles of the roof and floor sometimes become mixed with the coal in loading.

The bed was measured and sampled at five points in the mine by G. H. Deike and Edwin Higgins on November 9, 1912, as described below:

Sections of coal bed in Parker Run mine.

Section	A		B		C		D		E	
Laboratory No.	15067		15068		15069		15070		15071	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Black shale	[a]0	1	..	..	..	..	..	..	..	..
Coal, streaked, bony	[a]0	1½	..	..	..	..	..	..	[a]0	½
Coal, hard, bright	1	0	2	1	3	10½	3	5	3	9½
"Sulphur" streak	[a]0	1½	[a]0	1	[a]0	1	[a]0	2	..	..
Coal, hard, bright	2	5	1	8	2	½	1	9	..	..
Coal streaked with bone	..	..	[a]0	½	..	..	..	..	[a]0	2½
"Sulphur" streak	[a]0	1	..	..	..	..	..	..	..	..
Coal, hard, bright	2	0	2	2½	..	..	..	..	2	0
Coal, dirty, streaked	..	..	..	..	..	..	..	..	0	2
Bony coal and black "rash"	[a]0	1½	[a]0	1	[a]0	1	[a]0	1	[a]0	1
Floor, fire clay.										
Thickness of bed	5	11½	6	2	6	1	5	5	6	3½
Thickness of coal sampled	5	5	5	11½	5	11	5	2	5	11½

[a] Not included in sample.

Section A (sample 15067) was cut from a pillar on the main entry at the mouth of right entry 7, 2,400 feet northeast of the mine mouth.

Section B (sample 15068) was measured at the face of room 8 off right entry 5.

Section C (sample 15069) was measured at the face of room 21 off right entry 3.

Section D (sample 15070) was cut from a pillar on the main air course at the mouth of left entry 2.

Section E (sample 15071) was measured at the face of the fourth left air course, 1,800 feet northeast of the mine mouth.

A composite sample was made by mixing the face samples 15068, 15069, and 15071. The results of an ultimate analysis of this sample are given under laboratory No. 15072.

Notes.—At the time of sampling the coal was undercut by hand and compressed air punchers and shot down with FFF black powder. Black powder was also used for brushing the roof and floor. All the coal was shipped as run-of-mine. Average daily output, 450 tons. Practically all of the coal was derived from advance workings. There was approximately 1,500 acres of unmined coal tributary to this opening. Probable life of mine, about 25 years.

WORTHINGTON. HUTCHINSON MINE.

Sample.—Bituminous coal; analyses Nos. 11152, 11153, 11154, and 11155 (p. 121).

Mine.—Hutchinson; Monongahela district; a slope mine 1 mile from Worthington, on the Baltimore & Ohio Railroad.

Coal bed.—Pittsburgh. Carboniferous age, Monongahela formation. Average thickness, 102 inches; dip, 1½° northwest; roof, firm, smooth, dark shale; floor, hard, smooth fire clay. There is a workable coal bed 120 feet above this bed.

The bed was measured and sampled at four points in the Hutchinson mine by A. A. Straub, on November 5, 1910, as described below:

Sections of coal bed in Hutchinson mine.

Section	A		B		C		D	
Laboratory No.	11152		11153		11154		11155	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	10[illegible]	2	8	3	[illegible]	2	8
Coal, bony	0	[illegible]	0	[illegible]	0	[illegible]	0	[illegible]
Coal	0	3[illegible]	0	5[illegible]	0	2[illegible]	0	3[illegible]
Coal, bony	0	[illegible]	0	[illegible]	0	[illegible]	0	[illegible]
Coal	0	3[illegible]	0	1[illegible]	0	7[illegible]	0	3[illegible]
Coal, bony	0	[illegible]	0	[illegible]	0	[illegible]	0	[illegible]
Coal	4	5[illegible]	4	2[illegible]	1	6[illegible]	4	2[illegible]
"Sulphur" band	..	..	..	..	[a]0	[illegible]	..	..
Coal	..	..	..	..	1	0	..	..
"Sulphur" band	..	..	..	..	[a]0	[illegible]	..	..
Coal	..	..	..	..	1	7[illegible]	..	..
Floor, clay.								
Thickness of bed	8	[illegible]	7	7¼	8	3[illegible]	7	7¼
Thickness of coal sampled	8	[illegible]	7	7¼	8	3[illegible]	7	7¼

[a] Not included in sample.

Section A (sample 11152) was measured on pillar 15 on left heading 3, 2,500 feet south from the mouth of the main slope.

Section B (sample 11153) was measured on pillar 20 on left heading 1, 1,500 feet south of the mouth of the main slope.

Section C (sample 11154) was measured at the face of room 8 off the fourth left butt entry, 3,000 feet south of the mouth of the main slope.

Section D (sample 11155) was measured at the face of room 10 off left heading 2, 1,000 feet south of the mouth of the main slope.

A composite sample was made by mixing samples 11152 to 11155, inclusive. The result of an ultimate analysis of this sample is given under laboratory No. 11156.

Notes.—The coal was mined by the room-and-pillar system. At the time of sampling black powder was used for breaking down the coal after undercutting by electric chain cutters; permissible explosives were used for brushing the roof. None of the coal was shipped as run-of-mine; coal was screened over 1¼ and ¾-inch bar screens; pickers were employed on the cars when loading; there were three loading tracks with capacity for 32 cars. Daily output of mine, 400 tons. About 60 per cent of the coal produced was from advance work. Recovery, 90 per cent when pillars are pulled. There was 151 acres of coal tributary to the main slope.

MARSHALL COUNTY.

MOUNDSVILLE. PANAMA MINE.

Sample.—Bituminous coal; analyses Nos. 14486, 14487, and 14488 (p. 122).

Mine.—Panama; Wheeling district; a shaft mine 1 mile south of Moundsville station, on the Baltimore & Ohio Railroad.

Coal bed.—Pittsburgh. Carboniferous age, Monongahela formation. Average thickness, 5 feet 6 inches. There is a distinct cleat extending north and south. Occasional clay veins are encountered. The immediate roof consists of a "draw slate" over which is a roof coal and shale with a limestone cap rock. Floor, underclay and limestone. Small amounts of the shale from the roof and underclay occasionally mix with the coal in mining. Cover at points of sampling, 400 feet.

The coal bed was measured and sampled at two points in the mine by G. H. Deike and J. T. Ryan on July 20, 1912, as described below:

Sections of coal bed in Panama mine.

Section	A		B	
Laboratory No.	14486		14487	
Roof, "draw slate", roof coal, and limestone.	*Ft.*	*in.*	*Ft.*	*in.*
Coal, bony	..	..	0	3
Coal	0	7	0	5
Mother coal	0	⅛	0	⅛
Coal	0	1	0	6
Mother coal	0	⅛	0	¼
Coal	1	1	0	6½
Shale, black	..	..	[a]0	1
Coal	..	..	0	5½
Coal, bony	..	..	0	2
Mother coal or "sulphur"	[a]0	1	0	½
Coal	2	0	0	9
Coal with streaks of mother coal and "sulphur"	0	4	0	7¾
"Sulphur" band	..	..	[a]0	1¼
Coal streaked with bony coal	0	7	0	8
Floor, underclay and limestone.				
Thickness of bed	4	9¼	4	7⅞
Thickness of coal sampled	4	8¼	4	5⅝

[a] Not included in sample.

Section A (sample 14486) was measured at the face of the second south air course, 2,050 feet southeast of the shaft.

Section B (sample 14487) was measured at the face of room 3 off right entry 2 off north entry 2, at a point 1,700 feet northeast of the shaft.

A composite sample was made by combining samples 14486 and 14487. The results of an ultimate analysis of this sample are given under laboratory No. 14488.

Notes.—The Panama mine is opened by a shaft 138 feet deep. The coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut with electric coal cutting machines and broken down with black powder. The machine cuttings were loaded out with the coal. About 35 per cent of the coal passed through the screens. The screening plant consisted of bars 12 feet long with 1¼ and ¾ inch openings. No pickers were employed on the cars or belt. The lumps were small. There were two loading tracks with a capacity of 15 loaded cars. Approximately 3,000 acres remained to be mined. The probable lifetime of the mine was 30 years. The maximum day's run was 650 tons. Average daily output, 450 tons.

MERCER COUNTY.

CRYSTAL. GODFREY MINE.

Sample.—Semibituminous coal; Norfolk & Western field; analyses Nos. 14258, 14259, and 14261 (p. 122).

Mine.—Godfrey, Pocahontas district, a drift mine ½ mile southeast of Crystal on the Wenonah branch of the Norfolk & Western Railway.

Coal bed.—Pocahontas No. 3. Carboniferous age, Pottsville formation. Average thickness, 4 feet 6 inches; dip, 1½ per cent northwest. Roof, smooth gray shale; floor, hard fire clay. Material from the roof and floor does not become mixed with the coal in mining. Cover, 150 to 200 feet.

The coal bed was measured and sampled at three points in the mine by D. J. Price, July 2, 1912, as described below:

Sections of coal bed in Godfrey mine.

Section	A		B		C	
Laboratory No.	14258		14259		14261	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	3	1	10	1	2
"Sulphur" band	[a]0	1	..	..	[a]0	1
Coal	0	5	..	..	0	6
Bone	[a]0	4	[a]0	3	[a]0	3
Coal	1	11	2	2	2	7
Floor, fire clay.						
Thickness of bed	4	0	4	3	4	7
Thickness of coal sampled	3	7	4	0	4	3

[a] Not included in sample.

Section A (sample 14258) was measured on the pillar of right entry 2, 1,100 feet northeast of the mine mouth.

Section B (sample 14259) was measured in room 3, left heading 2, off the old main entry, 700 feet southeast of the mine mouth.

Section C (sample 14261) was measured at the face of room 4, next to "Crystal."

A composite sample was made by mixing samples 14258 and 14259. The results of an ultimate analysis of this sample are given under laboratory No. 14260.

Notes.—The Godfrey mine is opened by drift entry and the coal mined by the room-and-pillar system.

At the time the mine was visited the coal was undercut by hand and shot down with FFF black powder. About 20 per cent of the coal mined was from advance workings and the remainder was from pillars. All of the coal was shipped as run-of-mine and pickers were employed on the cars in loading. The tipple was about 5,000 feet from the mouth of the mine. The distance from the foot of the incline to the tipple was about 2,000 feet. The loading track had a capacity for 14 empty and 17 loaded cars. Daily production, 100 tons. There was approximately 40 acres of unmined coal tributary to this entry.

GOODWILL. GOODWILL MINE.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14163, 14164, 14165, 14166, and 14167 (p. 123).

Mine.—Goodwill; Norfolk and Western district; a drift mine in Goodwill township, ½ mile northeast of Goodwill on a branch of the Norfolk & Western Railway.

Coal bed.—Pocahontas No. 3. Carboniferous age, Pottsville formation. Average thickness 4 feet 8 inches; dip, 2 per cent northwest. Rolls occur in the bottom of the coal, but no faults or horsebacks are encountered. The roof is a "draw slate" 8 inches thick, overlain with sandstone; the floor is a smooth shale about 15 inches thick, below which there is a small amount of coal and sandstone. Particles of the roof do not mix with the coal, although a small amount of the shale bottom becomes mixed with the coal in mining. Cover at points of sampling, 300 to 400 feet.

The coal bed was measured and sampled at four points in the mine by D. J. Price on June 24 and 25, 1912, as described below:

Sections of coal bed in Goodwill mine.

Section	A		B		C		D	
Laboratory No.	14163		14164		14165		14166	
Roof, sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	1	1	1¾	1	4	1	3
Bone and "sulphur"	[a] 0	5	[a] 0	5	[a] 0	5	[a] 0	4½
Coal	3	3	3	2¼	2	9	2	10
Floor, shale.								
Thickness of bed	4	9	4	9	4	6	4	5½
Thickness of coal sampled	4	4	4	4	4	1	4	1

[a] Not included in sample.

Section A (sample 14163) was measured at the face of room 16, eighth left cross entry, 3,700 feet north of drift mouth No. 3.

Section B (sample 14164) was measured at the face of room 3, off second crosscut off Smith's entry, 3,000 feet northeast of drift mouth No. 3.

Section C (sample 14165) was measured at the face of the first crosscut off Nichol's entry, 2,850 feet east of drift mouth No. 2.

Section D (sample 14166) was measured on a pillar, 2,400 feet east of drift mouth No. 2.

A composite sample was made by combining pillar sample 14166 and face samples 14163, 14164, and 14165. The ultimate analysis of this sample is represented by laboratory No. 14167.

Notes.—The Goodwill mine is opened by 3 drift entries 2,388 feet above sea level. The coal is mined by the room-and-pillar method. At the time of sampling the coal was undercut by hand and electric short wall machines. The undercuttings were loaded out with the coal. The coal was broken down with FFF black blasting powder and a permissible powder was used for brushing the floor and roof. Although all the coal was shipped as run-of-mine, the tipple was equipped with screens as follows: Bars 8 by 12 feet with 3-inch openings, and 8 by 12 feet with ⅜-inch openings. Pickers were employed on the cars in loading. The screens were not washed or coked. The loading track had a capacity for 12 empty and 15 loaded cars. The mine was being run at its capacity, 350 tons per day. About 50 per cent of the coal came from advance workings and 50 per cent from pillars. There was about 400 acres of coal to be taken out from the three openings.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, Bureau of Mines, 1913, pp. 1023–1024.

GOODWILL. LOUISVILLE NO. 1, NO. 2, AND NO. 3 MINES.

Samples.—Semibituminous coal; Pocahontas field; analyses Nos. 14191, 14192, 14193, 14194, 14195, 14196, 14206, and 14207, p. 122.

Mines.—Louisville Nos. 1, 2, and 3; Norfolk & Western district; drift mines in Goodwill township. Mines 1 and 2 are ½ mile northwest and No. 3 is 1 mile northwest of Goodwill station on the Flipping Creek Branch of the Norfolk & Western Railway.

Coal bed.—Pocahontas No. 3. Carboniferous age, Pottsville formation. Average thickness, 4 feet 8 inches, dip 2 per cent northwest. The roof is a "draw slate" which is smooth and does not become mixed with the coal in mining. The "draw slate" is 8 inches to 4 feet thick, above which is a sandstone cap rock. The floor is a smooth, fairly hard shale in which are thin streaks of coal. Cover at points of sampling, 300 to 400 feet.

The coal bed was measured and sampled at one point in No. 1 mine, at four points in No. 2 mine, and at two points in No. 3 mine by G. H. Deike on June 24, 1912, as described below:

Sections of coal bed in Louisville No. 1, No. 2, and No. 3 mines.

Section	A		B		C		D		E		F		G	
Laboratory No.	14191		14192		14193		14194		14195		14206		14207	
Roof, sandstone.														
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Coal, streaked with mother coal	1	1	1	1½	1	1½	1	2½	1	2	1	1½	1	0
"Sulphur" band	*a* 0	½	*a* 0	½	*a* 0	½	..	..	*a* 0	½	*a* 0	½	..	..
Coal	..	..	*a* 0	½	*a* 0	½	..	..	*a* 0	½	*a* 0	½	..	..
Coal, bony	*a* 0	4½	*a* 0	3	*a* 0	3	*a* 0	2½	*a* 0	3	*a* 0	3	*a* 0	5
Coal	..	..	1	4	0	5	1	0	0	8	2	6	..	..
Coal, gray	..	..	0	¼	0	½	0	½	0	¼	0	½	..	..
Coal	..	..	0	6	..	..	..	..	0	11	..	..	..	..
Coal, gray	..	..	0	½	..	..	..	..	0	¼	..	..	..	..
Coal	3	2	1	2	2	7½	2	2½	1	11½	0	9	3	5
Floor, shale.														
Thickness of bed	4	8	4	6¾	4	6½	4	8	5	1	4	9	4	10
Thickness of coal sampled	4	3	4	2¼	4	2½	4	5½	4	9	4	5	4	5

a Not included in sample.

Section A (sample 14191) was measured at the face of the main entry, 5,400 feet northeast of mouth of No. 2 mine.

Section B (sample 14192) was measured at the face of room 19, off left heading 9, 5,700 feet northeast of mouth of No. 2 mine.

Section C (sample 14193) was measured on the rib of room 14, off left heading 6, 4,500 feet northeast of mouth of No. 2 mine.

Section D (sample 14194) was measured on the rib of room 13, off left heading 4, 3,000 feet northeast of mouth of No. 2 mine.

Section E (sample 14195) was measured on the barrier pillar between the second left air course and second left pillar, 1,500 feet northwest of mouth of No. 3 mine.

Section F (sample 14206) was measured at the face, 1,950 feet northeast of mouth of No. 3 mine.

Section G (sample 14207) was measured on the pillar of main entry, 900 feet northeast of mouth of No. 1 mine.

A composite sample was made by mixing samples 14191, 14192, 14193, 14194, 14195, 14206, and 14207. The results of an ultimate analysis of this sample are shown under laboratory No. 14196.

Notes.—The mines are opened by drifts and the coal is mined by the room-and-pillar system. At the time the mine was visited electric coal cutters were used for undercutting the coal; FFF black powder was used for breaking down the coal and a permissible explosive for brushing the roof. About 20 per cent of the coal was shipped as run-of-mine and 25 per cent as slack. The screening plant had one shaking screen with 5-inch openings and one bar screen with 3-inch openings. The smaller coal was run over a bar screen with openings of 1 inch to 1¼ inches. Pickers were employed on the cars in loading. The washery had a daily capacity of 1,200 tons. The screenings were coked. The coking plant had a capacity of 125 tons per day. There were two loading tracks with a capacity for 50 empty cars and 20 loaded cars. The storage bins had a capacity for 150 tons. The coal when loaded on the cars had a good appearance and the lumps were large. There was approximately 400 acres of unmined coal tributary to these openings. About 40 per cent of the coal mined was from the advance workings. Daily output, 1,000 tons.

MATOAKA. PAWAMA NO. 1 AND NO. 2 MINES.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14231, 14232, 14233, 14234, 14235, 14236, and 14237 (p. 123).

Mine.—Pawama No. 1 and No. 2; Norfolk & Western district; drift mines at Matoaka, on the Norfolk & Western Railway and near the Virginia Railway.

Coal bed.—Pocahontas No. 3. Carboniferous age, Pottsville formation. Average thickness, 4 feet 4 inches; dip, 1½° northwest. There are no faults, rolls, or horsebacks. There is a characteristic bone parting about 3 inches thick near the middle of the bed. The roof consists of 12 inches of "draw slate," which was shot down after loading out the coal. Floor, soft smooth underclay. Cover at points of sampling, 150 to 175 feet.

The coal bed was measured and sampled at five points in the mines by J. J. Rutledge and D. J. Price on July 1, 1912, as described below:

Sections of coal bed in Pawama No. 1 and No. 2 mines.

	No. 2 mine.			No. 1 mine.	
Section	A	B	C	D	E
Laboratory No	14231	14232	14233	14235	14236
Roof, gray shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	1 0	1 0	0 10	0 10½	1 0
"Sulphur" and bone	[a] 0 ¼	[a] 0 ¼	[a] 0 1	[a] 0 3	[a] 0 2
Coal	0 7	0 8½	0 7	0 9	0 9½
Bone	[a] 0 2½	[a] 0 2½	[a] 0 4½	[a] 0 4	[a] 0 3
Coal	2 7	2 4½	2 7	2 5	2 2
Floor, underclay.					
Thickness of bed	4 4¾	4 3¾	4 5½	4 7½	4 5
Thickness of coal sampled	4 2	4 1	4 0	4 ½	3 11½

[a] Not included in sample.

Section A (sample 14231) was measured at the face of the Roanoke heading, 2,060 feet southwest of the drift mouth of No. 2 mine.

Section B (sample 14232) was measured at the face of the main entry, 2,600 feet southwest of the drift mouth of No. 2 mine.

Section C (sample 14233) was measured at the face of room 20, off Norfolk entry, 2,300 feet southwest of the drift mouth of No. 2 mine.

A composite sample was made by combining and mixing samples 14231, 14232, and 14233. The results of an ultimate analysis of this sample are given under laboratory No. 14234.

Section D (sample 14235) was measured on pillar of room 14, off Walker heading, 1,000 feet north of the drift mouth of No. 1 mine.

Section E (sample 14236) was measured on pillar on Godfrey heading, 1,520 feet southwest of the drift mouth of No. 1 mine.

A composite sample was made by mixing pillar samples 14235 and 14236. The results of an ultimate analysis of this sample are given under laboratory No. 14237.

Notes.—The Pawama mines are opened by a drift about 2,600 feet above sea level and are worked by the room-and-pillar system. At the time of sampling the coal was undercut by hand and broken down with FFF black blasting powder. About 80 per cent of the coal was shipped as run-of-mine. The remainder was passed over bar screens 12 feet long with 4-inch openings. Pickers and trimmers were employed on the cars. There were two loading tracks with a capacity of 18 empty cars and 14 loaded cars. Daily output, 450 tons, with a maximum day's run of 700 tons.

Mora. Crane Creek No. 1 and No. 2 Mines.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. W32517, W32518, W32519, W32520, W32600, W32601, W32602, and W32603 (pp. 124, 125).

Mine.—Crane Creek No. 1 and No. 2, Norfolk & Western district, slope mines, ½ mile west of Mora on the Pocahontas division of the Norfolk & Western Railway.

Coal bed.—Known as Pocahontas No. 3. Carboniferous (Pottsville) age, Pocahontas formation. Thickness, 4 feet to 6 feet 6 inches. Roof, sandstone and shale; floor, shale. A "rash" 1 to 4 inches thick overlies the coal; this is removed from all run-of-mine coal at the tipple by passing the coal over 3-inch screens. The coal from this bed is of very good quality, and can easily be cleaned from partings.

The coal bed was measured and sampled at eight points in the mine on July 19 and 20, 1912, by P. M. Riefkin, as described below:

Sections of coal bed in Crane Creek No. 1 mine.

Section	A		B		C		D	
Laboratory No.	W32517		W32518		W32519		W32520	
Roof, sandstone and shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, hard, gray	..	..	..	..	0	4	..	..
Coal	0	9¾	0	9	0	7½	0	10
Bony coal to "sulphur"	[a] 0	2¼	[a] 0	2	[a] 0	¾	[a] 0	1½
Coal	0	6	0	7	0	11½	3	5½
Coal, hard, gray	0	2½	0	3¾	..	..	..	..
Mother coal	..	..	..	..	0	¼	..	..
Coal	2	5½	2	5	0	8	..	..
Shale	..	..	[a] 0	2½	..	..	..	..
Mother coal	0	2	..	..	0	¼	..	..
Coal	..	..	0	3¾	1	11½	..	..
Bony coal to shale	[a] 0	2¼	..	..	[a] 0	4	..	..
Coal	0	4¾	..	..	0	8	..	..
Floor, shale.								
Thickness of bed	4	11	4	9	5	7¾	4	5
Thickness of coal sampled	4	6½	4	4½	5	3	4	3½

[a] Not included in sample.

Section A (sample W32517) was measured at the face of the main heading.

Section B (sample W32518) was measured at the face of eighteenth cross air course.

Section C (sample W32519) was measured on the pillar beyond the second cut-through in room 11 off cross entry 16.

Section D (sample W32520) was measured on the pillar beyond the second cut-through in room 21 off cross entry 6, off the main heading.

Sections of coal bed in Crane Creek No. 2 mine.

Section	A		B		C		D	
Laboratory No.	W32600		W32601		W32602		W32603	
Roof, sandstone and shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Muck	[a] 0	2	..	..	..	..	[a] 0	2
Coal	0	5¼	0	10½	0	9½	0	8
Mother coal (hard)	0	¼	..	..	..	..	0	1½
Coal	0	5	..	..	..	..	0	½
Coal, bony	[a] 0	1	[a] 0	3	[a] 0	1¾	[a] 0	3
Coal	..	..	2	0	0	6½	0	7
Coal, hard, gray	..	..	0	4	0	3	0	2
Coal	3	6	1	2	2	7½	1	8½
Mother coal, hard, to shale	[a] 0	1	[a] 0	2	Streak.		0	1
Coal	..	..	..	..	0	1	..	..
Mother coal, hard, bony	..	..	..	..	[a] 0	2	[a] 0	2½
Coal	[a] 0	4	0	5½	0	5½	0	8½
Floor, fire clay and shale.								
Thickness of bed	5	½	5	3	5	¾	4	8½
Thickness of coal sampled	4	4½	4	10	4	9	4	1

[a] Not included in sample.

Section A (sample W32600) was measured in a pocket above the second cut-through in room 4, off cross entry 3.

Section B (sample W32601) was measured at the face of room 14, off Allegheny entry.

Section C (sample W32602) was measured on a chain pillar between rooms 21 and 22, off Blue Ridge entry.

Section D (sample W32603) was measured at the face of room 13, off Bryant entry.

Notes.—The Crane Creek No. 1 and No. 2 mines dumped coal over the same tipple. At the time of sampling the coal in these mines was undercut by hand with picks in the bottom part of the seam, and shot down with black powder. The tipple was constructed of wood and steel, and equipped with a 3-inch bar screen, a 2-inch, 1½-inch, 1-inch and ⅝-inch revolving screen, and a picking table. The inspection and preparation of this coal was exceptionally good; all coal passing over the 4-inch screen was shipped as run-of-mine coal, and passed over a picking table before going into the railroad cars. The commercial sizes as shipped, besides run-of-mine, were egg and stoker coal. All of the coal which passed through the ⅝-inch mesh of the revolving screen was washed. The washed coal was not shipped, but was coked.

The average output of the two mines was 1,000 tons per day, with a daily capacity of 1,750 tons. The unmined area was about 3,800 acres.

For analyses and descriptions of other samples of coal from this mine, see Bull. 22, Bureau of Mines, 1913, pp. 1026–1027.

MORA. PINNACLE MINE.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. W32604, W32605, W32606, W32607, W32608, and W32609 (p. 125).

Mine.—Pinnacle; Norfolk & Western district; a slope mine; 1 mile north of Mora on the Pocahontas division of the Norfolk & Western Railway.

Coal bed.—Known as Pocahontas No. 3. Carboniferous (Pottsville) age, Pocahonta, formation. The coal in this mine is 4 to 5 feet 6 inches thick. Roof and floor goods a "rash" 1 to 4 inches thick overlies the coal; this is eliminated from run-of-mine coal at the tipple by bar screens. The coal from this bed is of a good quality and can easily be cleaned.

The coal bed was measured and sampled at six points in the mine by P. M. Riefkin on July 21, 1912, as described below:

Sections of coal bed in Pinnacle mine.

Section	A		B		C		D		E		F	
Laboratory No.	W32604		W32605		W32606		W32607		W32608		W32609	
Roof, shale and sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Muck and "draw slate"	a0	1	a0	1½	a0	2½	a0	3	a0	1½	a0	1
Coal, gray	..	..	..	..	..	..	..	..	0	6½	..	..
Coal	1	2½	0	11¼	1	0	0	10	0	5	0	11
Mother coal	..	..	0	¼	..	..	0	½	..	..	0	½
"Sulphur"	..	..	..	..	..	..	..	..	a0	¾	a0	1½
Coal, bony	a0	2	..	..	a0	3	..	..	..	..	..	..
Coal	1	6¼	0	1¼	3	3	0	5½	0	5½	0	2
Mother coal, hard, bony	..	..	0	¼	..	..	..	..	..	..	..	..
Coal	..	..	0	2	..	..	..	..	..	..	..	..
Coal, bony	0	½	a0	3	..	..	a0	2¾	a0	2	a0	2½
Coal	1	2½	2	8½	..	..	3	0	2	11	3	4½
Mother coal	..	..	0	½	..	..	..	..	..	..	..	..
Floor, shale.												
Thickness of bed	4	2¾	4	4½	4	8½	4	9¾	4	8¼	4	11
Thickness of coal sampled	3	11¾	4	0	4	3	4	4	4	4	4	6

a Not included in sample.

Section A (sample W32604) was measured at the face of cross entry 2, north mine.

Section B (sample W32605) was measured at the face of the north main heading.

Section C (sample W32606) was measured at face of a pocket in the first pillar of room 25, cross entry 2, off main heading.

Section D (sample W32607) was measured at the face of cut-through off Cuba entry, off the second main heading.

Section E (sample W32608) was measured at the face of main heading 2.

Section F (sample W32609) was measured on a pillar of room 16, off cross entry 4, off the first main heading.

Notes.—At the time of sampling the coal in this mine was undercut in the bottom part of the seam by hand with picks, and shot down with black powder. The tipple was constructed of wood and equipped with a 3-inch bar screen and a 2-inch, 1½-inch, 1-inch, and ⅝-inch revolving screen, washer, and picking table. The inspection and preparation of the coal for the market was exceptionally good. The coal was picked on a picking table and on the cars after passing over the 4-inch bar screen. The coal that passed through the 4-inch screen fell into the revolving screen, and the screened coal was shipped as egg and stoker coal. All the coal that passed through the ⅝-inch mesh revolving screen was washed. Very little of the washed coal was shipped, practically all of it being coked. Average daily output, 1,000 tons, with a capacity of 1,600 tons per day. The unmined area was about 1,700 acres.

For analyses and descriptions of other samples of coal from this mine see Bulletin 22, Bureau of Mines, 1913, pages 1027–1028.

MORA. SAGAMORE NO. 1 AND NO. 2 MINES.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14250, 14251, 14252, 14253, 14254, 14255, 14256, and 14257 (p. 125).

Mine.—Sagamore No. 1 and No. 2; Norfolk and Western district; drift mines 1 mile west and 1 mile east of Mora, respectively, both on the Crane Creek branch of the Norfolk & Western Railway.

Coal bed.—Pocahontas No. 3. Carboniferous (Pottsville) age, Pocahontas formation. Average thickness of bed in No. 1 mine about 5 feet, in No. 2 mine about 4 feet 6 inches. Roof, smooth, dark, soft, sandy shale, 10 to 24 inches thick. Floor, light-gray shale, smooth, and fairly hard. Occasionally a small amount of the roof material becomes mixed with the coal, but none of the floor is broken loose during mining operations. Cover at points of sampling, 250 to 400 feet.

The coal bed was measured and sampled at three points in No. 1 mine and at four points in No. 2 mine by H. I. Smith and G. H. Deike, July 2, 1912, as described below:

Sections of coal bed in Sagamore No. 1 mine.

Section	A		B		C	
Laboratory No.	14250		14251		14252	
Roof, sandy shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	9	0	9	0	10
Coal, bony	[a] 0	4	[a] 0	3½	[a] 0	6
Coal	..	..	0	9	0	9
Coal, gray	..	..	0	1½	0	1½
Coal	..	..	0	6	..	..
Coal, gray	..	..	0	½	..	..
Coal	3	2	2	1	2	0
Mother coal	..	..	..	..	0	½
Coal	..	..	..	..	0	6
"Rash"	[a] 0	9	[a] 0	6	[a] 0	6
Coal (streaked)	..	..	0	6	0	8
Floor, shale.						
Thickness of bed	5	0	5	6½	5	11
Thickness of coal sampled	3	11	4	9	4	11

[a] Not included in sample.

Section A (sample 14250) was measured at the face of the main straight entry H, 2,250 feet northwest of the mine mouth.

Section B (sample 14251) was measured at the face of G–1 heading, 2,250 feet west of the mine mouth.

Section C (sample 14252) was measured at the face of room 11 off G–2 heading, 1,900 feet southwest of the mine mouth.

Sections of coal bed in Sagamore No. 2 mine.

Section	A		B		C		D	
Laboratory No.	14253		14254		14255		14256	
Roof, sandy shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	4	1	0	0	3	0	11½
Coal, gray	0	2	..	..	0	2	..	..
"Sulphur" band	..	..	..	..	..	..	0	¼
Coal	0	6½	..	..	0	7	0	2¼
"Sulphur" band	0	½	[a] 0	½	[a] 0	½	..	..
Bone	[a] 0	4	[a] 0	3½	[a] 0	3½	0	½
Coal	..	..	0	7½	0	7	0	6½
Coal, gray	..	..	0	3½	0	3	0	3
Coal	2	3	2	2½	2	4	1	9
Mother coal	0	½	..	..	..	..	0	½
Coal	0	9½	..	..	..	..	0	8½
Floor, shale.								
Thickness of bed	4	6	4	5½	4	6	4	6
Thickness of coal sampled	4	2	4	1½	4	2	4	6

[a] Not included in sample.

Section A (sample 14253) was measured at the face of H–8 entry, 2,550 feet southeast of the mine mouth.

Section B (sample 14254) was measured at the face of G–6 entry, 2,300 feet southwest of the mine mouth.

Section C (sample 14255) was measured at the face of G–8 entry, 2,550 feet south of the mine mouth.

Section D (sample 14256) was measured at the face of the straight H air course, 2,350 feet southeast of the mine mouth.

A composite sample was made by mixing face samples 14250 to 14256, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14257.

Notes.—The Sagamore mines are opened by drift entries and the coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by electric chain machines and by hand. FFF black powder was used for breaking down the coal and a permissible explosive for brushing the roof. About 30 per cent of the coal was shipped as run-of-mine. The screening plant was equipped with shaking screens 5 by 12 feet with openings 4 by 6 inches. About 75 per cent of the coal passed through this screen. The smaller sizes of coal were run over shaking screens 5 by 20 feet, with holes 3 inches, 1½ inches, and 1 inch in diameter. There were two belt conveyors at which a number of pickers were employed. The screenings were washed, yielding coal of a maximum size of 1½ inches and producing nut and slack coal. The washery had a capacity of 600 tons per day. There were 3 loading tracks with a capacity of 40 empty and 50 loaded cars and storage bins for 200 tons. The tipple and washery equipment was very complete and the preparation for market was thorough. The coal being loaded was chiefly in large lumps which had a good appearance. Daily output of the two mines, 800 tons. There was about 3,000 acres of unmined coal, a large part of which was tributary to the two mines. About 30 per cent of the output was from advance workings and the remainder from pillars.

WEYANOKE. WEYANOKE NO. 1 AND NO. 2 MINES.

Sample.—Semibituminous coal; Pocahontas field; analyses Nos. 14224, 14225, 14226, 14227, 14228, 14229, and 14230 (p. 126).

Mine.—Weyanoke No. 1 and No. 2, Norfolk & Western district; drift mines about one-fourth mile north of Weyanoke station on the Wenonah branch of the Norfolk & Western Railway.

Coal bed.—Pocahontas No. 3. Carboniferous (Pottsville) age, Pocahontas formation. Average thickness, 4 feet. There are no faults or horsebacks, but there are occasional rolls and local dips. The cleat is well marked. The roof consists of about 8 inches of "draw slate," which is taken down after loading out the coal. Above the "draw slate" is a main cap rock. Particles of the roof sometimes got mixed with the coal. The floor consists of 8 to 10 inches of dark shale, under which is 4 inches of coal; under the coal is sandstone. Cover, 300 to 400 feet.

The coal bed was measured and sampled at 4 points in No. 1 mine and at 2 points in No. 2 mine by H. I. Smith and G. H. Deike on July 1, 1912, as described below:

Sections of coal bed in Weyanoke No. 1 and No. 2 mines at Weyanoke.

Section	A		B		C		D		E		F	
Laboratory No.	14224		14225		14226		14227		14228		14230	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Cannel (cube) coal	[a]0	½	[a]0	1	[a]0	½	[a]0	1	[a]0	1	[a]0	1
Coal	1	0	0	10	1	0	1	0	0	9	1	0
Bone, gray	..	..	[a]0	1½	[a]0	2½	0	⅛	0	½	[a]0	4
Coal	..	..	0	4	..	..	0	2	0	2	1	9
Coal, gray	[a]0	2	0	4	..	..	0	⅛	[a]0	2¼	0	½
Coal	..	..	..	..	..	..	0	7	1	4	..	..
Mother coal	..	..	..	..	..	..	0	⅜	0	¼	..	..
Coal	2	11	2	4	3	3	2	1⅜	1	8¾	1	1½
Floor, dark shale.												
Thickness of bed	4	1½	4	½	4	6	4	0	4	3¾	4	4
Thickness of coal sampled	3	11	3	10	4	3	3	11	4	0	3	11

[a] Not included in sample.

Section A (sample 14224) was measured at the face of room 11, off left entry 9, off main heading of No. 1 mine.

Section B (sample 14225) was measured at the face of the main air course of No. 1 mine.

Section C (sample 14226) was measured at the face of room 22, off eighth left cross heading of No. 1 mine.

Section D (sample 14227) was measured at the face of right entry 3, off main entry of No. 2 mine.

Section E (sample 14228) was measured at the face of room 6, off left entry 6 of No. 1 mine.

Section F (sample 14230) was measured on pillar of last crosscut in room 7, off second left butt entry of No. 2 mine.

A composite sample was made by combining and mixing samples 14224, 14225, 14226, 14227, and 14228. The results of an ultimate analysis of this sample are given under laboratory No. 14229.

Notes.—The Weyanoke mines are opened by drifts and the coal is mined by the room-and-pillar system. At the time of sampling the coal was top cut by electric chain machines and broken out with FFF black blasting powder; permissible explosives were used for brushing the floor and roof. The machine cuttings were loaded out with the coal. None of the coal was shipped as run-of-mine, and about 25 per cent passed through bar screens 16 feet long having 1¼-inch openings. Twelve men were employed as pickers on the belt. The lumps on the car were large and had a good appearance. There were two loading tracks, with a capacity of 25 empty cars and 30 loaded cars. Most of the coal was shipped for domestic purposes. The daily output of both mines was 600 tons, with a maximum day's run of 1,000 tons. Ten per cent of the coal came from advance workings and the remainder from pillars. About 1,000 acres remained to be mined through the existing openings.

MONONGALIA COUNTY.

RICHARD. ELKINS NO. 1 MINE.

Sample.—Bituminous coal; analyses Nos. W12204, W19475, W19476, W19477, W19478, and W19479 (pp. 126, 127).

Mine.—Elkins No. 1; Monongahela district; a slope mine ½ mile northeast of Richard, on the Morgantown & Kanawha Railroad, with connections to the Baltimore & Ohio Railroad at Rowlesburg.

Coal bed.—Upper Freeport. Carboniferous age, Allegheny formation. Average thickness, 4 feet. Roof, low-grade coal about 3½ feet thick, overlain by sandstone; floor, hard clay with smooth surface.

The bed was measured and sampled at five points in the mine by G. S. Pope, April 22, 1911, as described below:

Sections of coal bed in Elkins No. 1 mine.

Section	A		B		C		D		E	
Laboratory No	W19475		W19476		W19477		W19478		W19479	
Roof, coal and sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	8¾	2	7	2	6½	2	8	2	8½
Mother coal	0	¾	..	..	0	1	..	..	..	..
Coal	2	1¼	..	..	0	4	..	..	..	..
Shale	[a]0	1½	[a]0	1¼	[a]0	¾	[a]0	2¼	[a]0	2¼
Coal	0	11½	0	3	1	2	1	1	0	6
"Sulphur"	..	..	[a]0	⅜	..	..	..	..	..	..
Coal	..	..	0	3½	..	..	..	..	..	..
Mother coal	..	..	0	½	..	..	..	..	0	¼
Coal	..	..	0	4	..	..	..	..	0	7½
Coal and parting	[a]0	1	..	..	..	..	..	..	..	..
Floor, hard clay.										
Thickness of bed	4	¾	3	7⅝	4	2¼	3	11¼	4	½
Thickness of coal sampled	3	10¼	3	6	4	1½	3	9	3	10¼

[a] Not included in sample.

Section A (sample W19475) was measured at the face of the fifth right "flat," 4,200 feet northeast of the drift mouth.

Section B (sample W19476) was measured at the face of butt entry 8 off fifth right entry, about 700 feet from the main entry.

Section C (sample W19477) was measured at the face of first right heading, 4,200 feet from the drift mouth.

Section D (sample W19478) was measured at the face of butt entry 11, off first right entry, 750 feet from right entry 1.

Section E (sample W19479) was cut from butt entry 5, off fifth right "flat," 1,400 feet from fifth "flat."

A composite sample was made by mixing samples W19475, W19476, W19477, W19478, and W19479. The results of an ultimate analysis of this sample are given under laboratory No. W12204.

Notes.—The Elkins No. 1 mine is opened both by drift entries and a slope. At the time of sampling the coal was undercut by hand and machines and shot down with black powder. There were two loading tracks with a capacity for 20 cars. Pickers were employed on the cars in loading. The mine was equipped to produce 700 tons per day. Average daily output 425 tons, the larger part of which was from advance workings. There was about 500 acres of coal tributary to this and other openings.

PRESTON COUNTY.

MASONTOWN. ELKINS NO. 6 MINE.

Sample.—Bituminous coal; analyses Nos. W19493, W19494, W19540, and W19541 (p. 127).

Mine.—Elkins No. 6; Monongahela district; a drift mine at Masontown, on the Morgantown & Kanawha Railroad with connections to the Baltimore & Ohio Railroad at Rowlesburg.

Coal bed.—Upper Freeport. Carboniferous age, Allegheny formation. Average thickness, 4 feet. Roof, shale, bone, and dirty coal, overlain by sandstone; floor, smooth hard fire clay.

The bed was measured and sampled at four points in the mine by G. S. Pope, April 24, 1911, as described below:

Sections of coal bed in Elkins No. 6 mine.

Section	A		B		C		D	
Laboratory No.	W19493		W19494		W19540		W19541	
Roof, shale, bone, dirty coal and sandstone.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	2⅝	1	9⅝	2	0	2	8
"Sulphur"	0	⅜	..	..	..	..	..	..
Coal	0	6	..	..	..	..	..	..
Mother coal	0	⅜	0	½	0	¼	..	..
Coal	0	10	0	8	0	7¼	..	..
Shale	ᵃ0	1¼	ᵃ0	2⅝	ᵃ0	2	ᵃ0	2⅝
Coal	0	3¼	0	3¼	0	4	0	3¼
Bone	0	¼	0	¼	0	¼	0	⅜
Coal	0	8½	0	9¼	0	7¼	0	9
Shale	0	⅛	0	⅛	0	⅛	0	⅛
Coal	0	3¼	0	2¾	0	3	0	3⅛
Floor, hard, smooth fire clay.								
Thickness of bed	4	⅞	4	1⅜	4	1⅞	4	3⅞
Thickness of coal sampled	3	11⅝	3	11⅜	3	11⅝	4	1⅛

ᵃ Not included in sample.

Section A (sample W19493) was measured at the face of the first butt heading, 600 feet from the third "flat," 150 feet from the main entry.

Section B (sample W19494) was measured at the face of the third right entry, 50 feet from the main entry.

Section C (sample W19540) was measured at the face of the second butt heading, 1,000 feet from the main entry.

Section D (sample W19541) was measured at the face of the second butt entry, 700 feet from the second "flat," 300 feet from the main entry.

A composite sample was made by mixing samples W19493, W19494, W19540, and W19541. The results of an ultimate analysis of this sample are given under laboratory No. 12225.

Notes.—The Elkins No. 6 mine is opened by a drift entry. The mine is comparatively new, and only a few side entries have been started. At the time of sampling the coal was undercut by hand and broken down with black powder. There was one loading track at the tipple with a capacity of 15 cars. There were no screens, the entire production being shipped as run-of-mine. Pickers were employed on the cars in loading. All of the coal was used for coking purposes. There was 1,200 acres of unmined area tributary to this opening.

RALEIGH COUNTY.

HOTCOAL. BIG STICK MINE.

Sample.—Semibituminous coal; New River field; analyses Nos. 14375, 14376, 14377, and 14378 (p. 127).

Mine.—Big Stick; Kanawha-New River district; a drift mine at Hotcoal, with railroad connections to the Virginian Railway.

Coal bed.—Beckley. Carboniferous age, Pottsville formation. Average thickness, 5 feet 6 inches; dip, 2½° northeast. The roof consists of 3 inches of "draw slate," above which is 2 feet of dark carbonaceous shale mixed with coal, above which is sandstone cap rock. Floor, hard, smooth shale. Material from the roof and floor does not become mixed with the coal in mining. Cover, 150 to 250 feet.

The coal bed was measured and sampled at 3 points in the mine by J. J. Rutledge, July 8, 1912, as described below:

Sections of coal bed in Big Stick mine.

Section	A	B	C
Laboratory No	14375	14376	14377
Roof, "draw-slate," shale	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	[a]0 1	.. ..	[a]0 ¾
Shale, black	[a]0 1	.. ..	[a]0 1
Coal, dirty	[a]0 ¾	.. ..	[a]0 ¾
Coal	3 3	2 6	3 4
Mother coal	.. ..	0 ½	.. ..
Coal	.. ..	0 10	.. ..
Cannel coal	0 ¼	.. ..	0 3
Coal, bony	.. ..	0 ¾	.. ..
Coal	2 0	1 10	2 6
Floor, fire clay.			
Thickness of bed	5 6	5 3¼	6 3½
Thickness of coal sampled	5 3¼	5 3¼	6 1

[a] Not included in sample.

Section A (sample 14375) was measured at the face of left heading 2, 1,600 feet east of the mouth of the straight main entry.

Section B (sample 14376) was measured at the face of left entry 3, off the straight main entry, 1,400 feet northeast of the mine mouth.

Section C (sample 14377) was measured at the face of the straight main entry, 1,900 feet northeast of the mine mouth.

A composite sample was made by mixing face samples 14375, 14376, and 14377. The results of an ultimate analysis of this sample are given under laboratory No. 14378.

Notes.—The Big Stick mine is opened by two entries and the coal mined by the room-and-pillar system. At the time of sampling the coal was undercut by hand and shot down with FF black blasting powder. A permissible explosive was also used in some parts of the mine. All of the coal was shipped as run-of-mine. Pickers were employed on the car in loading. There was no screening plant. The mine was new having been in operation only about 1 year at the time of sampling. All of the coal was obtained from advance workings. Daily output, 450 tons per day, with a maximum capacity of 500 tons.

McQUADE. BLUE JAY No. 4 MINE.

Sample.—Semibituminous coal; New River field; analyses Nos. 14288, 14289, 14290, and 14291 (p. 128).

Mine.—Blue Jay No. 4; Kanawha-New River district; a drift mine at McQuade station 2 miles southeast of Raleigh, on the Piney branch of the Chesapeake & Ohio Railway.

Coal bed.—Beckley. Carboniferous age, Pottsville formation. Average thickness, 5 feet; slight dip, northwest. Roof, smooth shale 1 to 2 feet thick; floor, very soft fire clay; material from the roof and the floor does not become mixed with the coal in mining. Cover at points of sampling 75 to 100 feet.

The coal bed was measured and sampled at three points in the mine by D. J. Price, July 10, 1912, as described below:

Sections of coal bed in Blue Jay No. 4 mine.

Section	A	B	C
Laboratory No	14288	14289	14290
Roof, shale.	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	1 4	1 2	1 2
Bone and shale	[a]0 9	[a]0 3	.. ..
Coal, bony	.. ..	.. ..	0 3
Coal	2 10	3 0	3 0
Floor, soft fire clay.			
Thickness of bed	4 11	4 5	4 5
Thickness of coal sampled	4 2	4 2	4 5

[a] Not included in sample.

Section A (sample 14288) was measured on a pillar of the main heading about 600 feet east of the mine mouth.

Section B (sample 14289) was measured at the face of the second right heading, 400 feet south of the mine mouth.

Section C (sample 14290) was measured on the pillar of the first right heading, 250 feet south of the mine mouth.

A composite sample was made by mixing samples 14288, 14289, and 14290. The result of an ultimate analysis of this sample are shown under laboratory No. 14291.

Notes.—The Blue Jay No. 4 mine is opened by drift entries and the coal mined by the room-and-pillar system. At the time of sampling the coal was undercut by hand. As the mining operations were confined entirely to pillars, no powder was used in breaking the coal. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. Daily output, about 150 tons. There was one loading track with a capacity for 10 empty and 7 loaded cars.

RALEIGH. RALEIGH NO. 1 AND NO. 3 MINES.

Samples.—Semibituminous coal; New River field; analyses Nos. 10624, 10625, 10626, 10627, 10628, and 10630 (p. 128).

Mine.—Raleigh No. 1 and No. 3; Kanawha-New River district; slope mines at Raleigh, on the Chesapeake & Ohio Railway.

Coal bed.—Beckley. Carboniferous (Pottsville) age, Quinnimont formation. Average thickness, 52 inches; dip about 2° N. 50° W.; roof, shale 2 feet thick with a sandstone capping 90 feet thick; floor, hard, smooth, gray shale.

The bed was measured and sampled at five points in the mines by J. J. Rutledge on June 25, 1910, as described below:

Sections of coal bed in Raleigh No. 1 and No. 3 mines.

Section	A		B		C		D		E	
Laboratory No.	10624		10625		10626		10627		10630	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	4	1	4	1	0	..	..	1	3
Coal, soft	0	⅛	0	½	0	⅛	..	..	0	⅛
Coal	3	10½	2	9½	3	1¾	3	7½	3	10½
Floor, shale.										
Thickness of bed	5	2⅝	4	2	4	1⅞	3	7½	5	1⅝
Thickness of coal sampled	5	2⅝	4	2	4	1⅞	3	7½	5	1⅝

Section A (sample 10624) was measured on the left rib of left entry 7 opposite the mouth of right heading 1 in No. 3 mine.

Section B (sample 10625) was measured at the face of right entry 15 in No. 3 mine.

Section C (sample 10626) was measured at the last crosscut in the main entry in No. 3 mine.

Section D (sample 10627) was measured at the face of room 11 off right heading 12 in No. 3 mine.

Section E (sample 10630) was measured at the neck of the last break-through off right entry 6 in No. 1 mine.

A composite sample was made by mixing samples 10624 to 10627, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 10628.

Notes.—No. 1 and No. 3 mines are connected and in reality form but a single mine, opened by two drift entries; double entry, room-and-pillar system of mining. At the time of sampling black powder was used for breaking coal after undercutting with electric chain cutters; bar screens; capacity, 1,000 tons a day; two loading tracks with capacity for 40 cars; unmined area about 2,000 acres.

SLAB FORK. SLAB FORK NO. 1, NO. 2, NO. 3, NO. 4, AND NO. 5 MINES.

Sample.—Semibituminous coal; New River field; analyses Nos. 14313 to 14318, and 14325 to 14337 (pp. 129, 130).

Mines.—Slab Fork No. 1, No. 2, No. 3, No. 4, and No. 5; Kanawha-New River district; drift mines; Nos. 1, 2, 3, and 4 are about three-fourths of a mile northeast of Slab Fork; No. 5 is one-fourth of a mile south of Slab Fork, on the Virginian Railway.

Coal bed.—Beckley. Carboniferous (Pottsville) age, Quinnimont formation. Thickness, 3 feet 5 inches to 4 feet 7 inches. Dip slightly irregular, but the main direction is northwest. Roof, sandy shale containing about 3 inches of roof coal. The shale and roof coal combined vary in thickness from 18 inches to 3 feet, above which there is a sandstone cap rock. Floor, hard smooth clay. Material from the roof and floor did not become mixed with the coal in mining. Cover at points of sampling, 100 to 400 feet.

The coal bed was measured and sampled at 15 points in the five mines by G. H. Deike and H. I. Smith July 10 and 11, 1912, as described below:

Sections of coal bed in Slab Fork No. 1 and No. 4 mines.

Section	No. 4		No. 1	
Laboratory No.	14336		14337	
Roof, sandy shale.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	11	[a]0	1½
Shale	..	..	[a]0	½
Mother coal	0	¼	..	..
Coal	0	8½	2	7
"Sulphur"	..	..	Streak.	
Coal, gray	0	2	..	..
Coal	0	2½	..	..
Coal, gray	0	1	..	..
Coal	1	8	1	4
Coal, bony	[a]0	3	[a]0	4
Coal	..	..	0	11½
Floor, clay.				
Thickness of bed	4	¼	5	4½
Thickness of coal sampled	3	9¼	4	10½

[a] Not included in sample.

Section A (sample 14336) was measured at the face of the main entry, about 1,450 feet northwest of the mine mouth.

Section B (sample 14337) was measured on the pillar of room 7, off second right entry, 1,200 feet northeast of the mine mouth.

Sections of coal bed in Slab Fork No. 2 mine.

Section	A		B		C		D		E	
Laboratory No.	14325		14326		14328		14329		14330	
Roof, sandy shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	[a]0	3	[a]0	3	[a]0	3	[a]0	2	[a]0	2½
Shale	[a]0	1½	[a]0	3	[a]0	3	[a]0	1	[a]0	3½
Coal	0	5	0	2	0	2	0	1½	0	2
Coal, gray	0	2	0	4	0	4	0	4½	0	4
Coal	3	5	3	6	1	3½	2	2½	3	6
Mother coal	0	1	..	..	0	½	0	¼	..	..
Coal	0	9	..	..	1	10	1	4	..	..
Bone	[a]0	4	..	..	..	..	[a]0	1	..	..
Floor, clay.										
Thickness of bed	5	6½	4	6	4	2	4	4¾	4	6
Thickness of coal sampled	4	10	4	0	3	8	4	¾	4	0

[a] Not included in sample.

Section A (sample 14325) was measured on the pillar of third left entry, between rooms 7 and 8, 1,800 feet southwest of the mine mouth.

Section B (sample 14326) was measured on the pillar between rooms 8 and 10, off seventh left entry, 3,000 feet southwest of the mine mouth.

A composite sample was made by mixing pillar samples 14325 and 14326. The results of an ultimate analysis of this sample are shown under laboratory No. 14327.

Section C (sample 14328) was measured on the face of the first panel off the second drift, 4,200 feet south of the mine mouth.

Section D (sample 14329) was measured at the face of first right entry, off third left entry, 1,200 feet southeast of the mine mouth.

Section E (sample 14330) was measured at the face of fourteenth left entry, 150 feet from the straight main entry, 5,000 feet southwest of the mine mouth.

A composite sample was made by mixing face samples 14328, 14329, and 14330. The results of an ultimate analysis of this sample are shown under laboratory No. 14331

Sections of coal bed in Slab Fork No. 3 mine.

Section	A		B		C	
Laboratory No	14332		14333		14334	
Roof, sandy shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	..	..	[a]0	1½	0	1½
Shale	..	..	[a]0	1	[a]0	1
Coal, impure	..	..	[a]0	2	..	..
Coal	0	4	0	9½	1	½
Coal, hard	..	..	0	2	0	2
Coal, soft	..	..	1	2	..	..
Mother coal	..	..	0	½	..	..
Coal, bony	0	1½	..	..	..	..
Coal	..	..	0	4½	..	..
Mother coal	..	..	0	1	..	..
Coal	3	5	0	4½	2	9
Mother coal	..	..	[a]0	1	..	..
Shale, bony	[a]0	4	..	..	[a]0	3
Coal	1	0	0	8½	..	..
Coal, bony	[a]0	1	..	..	..	..
Floor, clay.						
Thickness of bed	5	3½	4	2	4	5
Thickness of coal sampled	4	10½	3	8½	4	1

[a] Not included in sample.

Section A (sample 14332) was measured at the face of the main air course, 2,450 feet southeast of the mine mouth.

Section B (sample 14333) was measured at the face of A entry, 2,350 feet southeast of the mine mouth.

Section C (sample 14334) was measured at the face of room 3, off the first right entry, 2,600 feet southeast of the mine mouth.

A composite sample was made by mixing face samples 14332, 14333, and 14334. The results of an ultimate analysis of this sample are given under laboratory No. 14335.

Sections of coal bed in Slab Fork No. 5 mine.

Section	A		B		C		D		E	
Laboratory No	14313		14314		14315		14316		14318	
Roof, sandy shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, gray	..	..	..	..	0	4	..	..	..	..
Coal	[a]0	2	..	..	0	6½	..	..	..	..
Coal with "sulphur"	..	..	..	..	..	..	[a]0	2½	..	..
Shale	[a]0	3	..	..	Streak.		[a]0	1	..	..
Coal	1	0	0	10	0	6	0	11½	1	0
Coal, gray	..	..	..	..	0	2½	..	..	..	..
Shale	[a]0	2	[a]0	½	..	..	0	½	0	½
Coal	..	..	0	7	0	2½	..	..	..	..
Coal, gray	..	..	0	2	0	2	..	..	..	..
Coal	2	10	1	11½	1	8	2	9	2	9
Floor, hard clay.										
Thickness of bed	4	5	3	7	3	7½	4	½	3	9½
Thickness of coal sampled	3	10	3	6½	3	7½	3	8½	3	9½

[a] Not included in sample.

Section A (sample 14313) was measured at the face of the main heading, 3,200 feet southwest of the mine mouth.

Section B (sample 14314) was measured at the face of room 15, off the sixth left ntry, 2,000 feet southwest of the mine mouth.

Section C (sample 14315) was measured at the last cut-through, off the third left entry, 1,900 feet southeast of the mine mouth.

Section D (sample 14316) was measured on the pillar of room 10, off the second left entry, 800 feet south of the mine mouth.

Section E (sample 14318) was measured on the pillar of fourth left entry, between rooms 13 and 14, 1,250 feet south of the mine mouth.

A composite sample was made by mixing samples 14313 to 14316, inclusive. The results of ultimate analysis of this sample are shown under laboratory No. 14317.

Notes.—All of these mines are opened by drift entries and the coal mined by the room-and-pillar system. At the time of sampling, electric chain machines were used for undercutting the coal in Nos. 2, 3, and 4 mines. Machines were not used in the other mines. A permissible explosive was used for breaking the coal and for brushing the roof. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. No. 5 mine was equipped with 2 loading tracks with a capacity for 15 empty and 15 loaded cars; the other mines have 2 loading tracks with a capacity for 40 empty and 40 loaded cars.

The capacity of the mines was as follows: No. 1 mine, 30 tons a day; No. 2 mine, 350 tons a day; No. 3 mine, 170 tons a day; No. 4 mine, 60 tons a day, and No. 5 mine, 425 tons, or a total capacity of 1,035 tons a day. About 35 per cent of the coal was obtained from advance work. There was approximately 1,800 acres of unmined coal tributary to the various openings.

WINDING GULF. LYNWIN MINE.

Sample.—Semibituminous coal; New River field; analyses Nos. 14319, 14320, 14321, 14322, 14323, and 14324 (p. 130).

Mine.—Lynwin; Kanawha-New River district; a drift mine, one-fourth of a mile south of Winding Gulf on the Winding Gulf branch of the Virginian Railway.

Coal bed.—Beckley. Carboniferous (Pottsville) age, Quinnimont formation. Average thickness 5 feet; dip, slight, to the northwest. Roof, light blue shale to which the coal adheres more or less; floor, hard smooth shale that does not become mixed with the coal in mining. Cover, 400 feet.

The coal bed was measured and sampled at five points in the mine by D. J. Price on July 11, 1912, as described below:

Sections of coal bed in Lynwin mine.

Section	A		B		C		D		E	
Laboratory No	14319		14320		14321		14322		14323	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	3	0	2	9	2	10	2	8	2	9
Shale and bone	[a] 0	4	[a] 0	5	[a] 0	5	[a] 0	7	[a] 0	6½
Coal	2	0	1	7	1	11	1	11	2	0
Floor, shale.										
Thickness of bed	5	4	4	9	5	2	5	2	5	3½
Thickness of coal sampled	5	0	4	4	4	9	4	7	4	9½

[a] Not included in sample.

Section A (sample 14319) was measured at the break-through to the air course at left entry 6, about 2,600 feet from the mine mouth.

Section B (sample 14320) was measured at the face of right heading 6, about 2,800 feet from the mine mouth.

Section C (sample 14321) was measured at the face of room 2, right heading 8, about 3,300 feet from the mine mouth.

Section D (sample 14322) was measured at the face of right heading 8, 3,400 feet from the mine mouth.

Section E (sample 14323) was measured at the face of the main heading, 3,200 feet from the mine mouth.

A composite sample was made by mixing face samples 14319 to 14323, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 14324.

Notes.—The Lynwin mine is opened by a drift entry and the coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by hand and broken down with FFF black powder and a permissible explosive. All of the coal was shipped as run-of-mine. The screening plant had bar screens 6 by 12 feet with 3-inch openings. Pickers were employed on the car in loading. The run-of-mine coal contained large lumps and presented a good appearance on the cars. There were two loading tracks with a capacity for 22 empty and 22 loaded cars. There was approximately 600 acres of unmined coal tributary to this opening. A large percentage of the coal was obtained from advance work. Daily output, 450 tons, with a capacity of 550 tons.

WINDING GULF. WINDING GULF NO. 1 AND NO. 2 MINES.

Sample.—Semibituminous coal; New River field; analyses Nos. 14368, 14369, 14370, 14371, 14372, 14373, and 14374 (p. 131).

Mine.—Winding Gulf No. 1; Kanawha-New River district; at Winding Gulf on the Winding Gulf branch of the Virginian Railway. No. 2 mine is 1 mile from Winding Gulf on Winding Gulf branch of the Chesapeake & Ohio Railway.

Coal bed.—Beckley. Carboniferous (Pottsville) age, Quinnimont formation. Average thickness, 4 feet 6 inches. Dip about 2° northwest. Roof, smooth gray shale; floor, hard fire clay. Material from the roof and floor does not become mixed with the coal in mining. Cover at points of sampling, 60 to 400 feet.

The coal bed was measured and sampled at three points in No. 1 mine and at two points in No. 2 mine by D. J. Price July 9, 1912, as described below:

Sections of coal bed in Winding Gulf No. 1 mine.

Section	A		B		C	
Laboratory No	14368		14369		14370	
Roof, shale	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	2	11	2	10	2	11
Coal, bony	[a] 0	3	[a] 0	3	[a] 0	4
Coal	1	2	1	3	1	6
Floor, fire clay.						
Thickness of bed	4	4	4	4	4	9
Thickness of coal sampled	4	1	4	1	4	5

[a] Not included in sample.

Section A (sample 14368) was measured at the face of room 14, off left entry 1, off the main right heading.

Section B (sample 14369) was measured at the face of the air course of the west entry.

Section C (sample 14370) was measured at the face of the main right heading.

A composite sample was made by mixing face samples 14368, 14369, and 14370. The results of an ultimate analysis of this sample are given under laboratory No. 14371.

Sections of coal bed in Winding Gulf No. 2 mine.

Section	A		B	
Laboratory No	14372		14373	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	3	0	3	2
Coal, bone	[a] 0	4	[a] 0	3
Coal	0	9	1	6
Floor, fire clay.				
Thickness of bed	4	1	4	11
Thickness of coal sampled	3	9	4	8

[a] Not included in sample.

Section A (sample 14372) was measured on the pillar at the break-through to right heading 1.

Section B (sample 14373) was measured at the face of left heading 2.

A composite sample was made by mixing samples 14372 and 14373. The results of an ultimate analysis of this sample are given under laboratory No. 14374.

Notes.—Both of these mines were comparatively new at the time of sampling. Both mines are opened by a slope and the coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by electric machines and broken down with permissible explosives. All of the coal was shipped as run-of-mine. Pickers were employed on the cars in loading. The average daily output of No. 1 mine was 400 tons.

WOODBAY. McALPIN No. 1 MINE.

Sample.—Semibituminous coal, New River field; analyses Nos. 14301, 14302, 14303, 14304, 14305, 14306, 14307, 14308, and 14309 (p. 131).

Mine.—McAlpin No. 1; Kanawha-New River district; a drift mine at Woodbay Station on the Winding Gulf branch of the Virginian Railway.

Coal bed.—Beckley. Carboniferous (Pottsville) age, Quinnimont formation. Average thickness, 5 feet; dip, 1½° northwest. Roof, shale 2 to 3 feet thick, containing streaks of coal, above the shale which is a cap rock; floor, a dark soft, smooth carbonaceous shale. Material from the roof and floor did not become mixed with the coal in mining. Cover at points of sampling, about 400 feet.

The bed was measured and sampled at eight points in the mine by J. J. Rutledge and D. J. Price, July 6, 1912, as described below:

Sections of coal bed in McAlpin No. 1 mine.

Section	A		B		C		D	
Laboratory No.	14301		14302		14303		14304	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, shale.								
Coal	3	1	2	7	2	3	2	9
Mother coal	0	⅛	..	..	..	..	0	¼
Coal	0	9⅝	1	3	1	4	0	11
Cannel coal	0	3	0	2	0	2	0	3
Coal	1	3	1	3	2	6	1	4
Floor, shale.								
Thickness of bed	5	4¾	5	3	6	3	5	3¼
Thickness of coal sampled	5	4¾	5	3	6	3	5	3¼

Sections of coal bed in McAlpin No. 1 mine.

Section	E		F		G		H	
Laboratory No.	14305		14306		14307		14308	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof, shale.								
Coal	3	3	3	3	3	2	3	3
Coal, bony	[a]0	4	[a]0	4½	[a]0	3½	[a]0	4½
Coal	0	11½	0	8	0	10	0	9
Floor, shale.								
Thickness of bed	4	6½	4	3½	4	3½	4	4½
Thickness of coal sampled	4	2½	3	11	4	0	4	0

[a] Not included in sample.

Section A (sample 14301) was measured at the face of the second panel, off left heading 3, off second main entry.

Section B (sample 14302) was measured at the face of the second main air course.

Section C (sample 14303) was measured at the face of room 10, second panel, left entry 2.

Section D (sample 14304) was measured at the face of room 3, first panel, left entry 3.

Section E (sample 14305) was measured on the pillar of main heading 1, between right entries 3 and 4.

Section F (sample 14306) was measured at the face of the second panel, off right heading 2.

Section G (sample 14307) was measured at the face of the fourth panel, off right heading 2.

Section H (sample 14308) was measured on the pillar of the air course, near right entry 2.

A composite sample was made by mixing samples 14301 to 14308, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 14309.

Notes.—The McAlpin No. 1 Mine is opened by drift entries and the coal mined by a combination of the room-and-pillar and panel systems. At the time of sampling the coal was undercut by electric punchers and shot down with a permissible explosive. A permissible explosive was also used for brushing the roof. All of the coal was shipped as run-of-mine. The mine was equipped with a screening plant in which the bar screens had 1½-inch openings. The coal was hand-picked prior to loading on a conveying table about 170 feet long. The coal presented a good appearance when loaded on the cars. There were two loading tracks with a capacity for 31 empty and 36 loaded cars. All of the coal was obtained from advance work. Output, 1,000 tons day, with a maximum output of about 1,500 tons.

RANDOLPH COUNTY.

MILL CREEK. TOLBERT AND SPIKER MINE.

Sample.—Bituminous coal; analysis No. 13561 (p. 132).

Mine.—Tolbert and Spiker; Monongahela district; on Mill Creek, 6 miles south of the town of Mill Creek.

Coal bed.—Sewell (?). Carboniferous age, Pottsville formation. Average thickness about 4 feet; dip, 8° west.

The bed was measured and sampled at one point by E. R. Lloyd on March 19, 1912, as described below:

Section of coal in Tolbert and Spiker mine.

Laboratory No.	13561	
Roof, dark shale.	*Ft.*	*in.*
Coal	1	7
Bone	[a]0	5
Coal	2	0
Shale.		
Thickness of bed	4	0
Thickness of coal sampled	3	7

[a] Not included in sample.

The sample was collected about 100 feet north of the mouth of the mine about 40 feet from the outcrop, under about 75 feet of cover. Average output, about 2½ tons a day. The mine is located on the northeast face of Rich Mountain, at an elevation of about 2,750 feet.

SPRUCE. HOPKINS MINE.

Sample.—Bituminous coal; analysis No. 13601 (p. 132).

Mine.—Hopkins; Monongahela district; about 9 miles southwest of Cheat Bridge, on Cheat River lumber road of West Virginia Pulp & Paper Co., and about 5 miles from Spruce.

Coal bed.—Sewell (?). Carboniferous age, Pottsville formation. Thickness at point where sampled, 4 feet 7 inches clear coal, which is about the average thickness within the mine. Roof and floor, shale. The mine is near the top of Cheat Mountain at an elevation of over 4,000 feet. Sample was collected in the mine 1,075 feet southwest of the mine mouth by E. R. Lloyd on March 20, 1912.

WYOMING.

CONVERSE COUNTY.

DOUGLAS. OUTCROP.

Sample.—Subbituminous coal; Glenrock field; analysis No. 11442 (p. 132).

Mine.—Outcrop in sec. 33, T. 40 N., R. 72 W., 50 miles north of Douglas, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—Lower Burned. Tertiary age, Fort Union formation. Thickness, 6 feet 5 inches. Roof, carbonaceous shale; floor, carbonaceous clay.

The bed was measured and sampled by V. H. Barnett on September 25, 1910, as described below:

Section of coal bed in outcrop, 50 miles north of Douglas.

Laboratory No	11442	
Roof, carbonaceous shale.	*Ft.*	*in.*
Coal with thin carbonaceous lenses	[a] 0	10
Coal	5	7
Floor, shale.		
Thickness of bed	6	5
Thickness of coal sampled	5	7

[a] Not included in sample.

GLENROCK. COUNTRY BANK.

Sample.—Subbituminous coal; Glenrock field; analysis No. 11048 (p. 132).

Mine.—Country bank in sec. 5, T. 37 N., R. 75 W., 20 miles north of Glenrock, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—Not named. Tertiary age, Fort Union formation. Thickness, 12 feet 8 inches; sandstone cap rock.

The bed was measured and sampled by C. H. Wegemann on September 29, 1910, as described below:

Section of coal bed in country bank, 20 miles north of Glenrock.

Laboratory No	11048	
Roof, sandstone.	*Ft.*	*in.*
Coal	5	0
Coal, bony	[a] 1	2
Bone	[a] 0	2
Coal, clean	[a] 3	10
Coal with 2 bone partings	[a] 2	6
Floor, not stated.		
Thickness of bed	12	8
Thickness of coal sampled	5	0

[a] Not included in sample.

Note.—The coal was mined intermittently from an open pit.

INEZ. DIAMOND MINE.

Sample.—Subbituminous coal; Glenrock field; analysis No. 14781 (p. 132).

Mine.—Diamond; Inez district; a slope mine in sec. 16, T. 33 N., R. 73 W., 1½ miles south of Inez, and of the Chicago & North Western Railway.

Coal bed.—Not named. Tertiary age, Fort Union formation. Thickness, 4½ to 5 feet; roof, fair shale; floor, good shale; dip, 17° NE.

The bed was measured and sampled on September 24, 1912, by V. H. Barnett, as described below:

Section of coal bed in Diamond mine.

Laboratory No.	14781	
Roof, shale.	*Ft.*	*in.*
Coal	4	3
Clay	0	1
Coal	0	4
Floor, shale.		
Thickness of bed	4	8
Thickness of coal sampled	4	8

The sample was obtained at the face of an entry 450 feet from the mine mouth.

INEZ. INEZ MINE.

Sample.—Subbituminous coal; Glenrock field; analysis No. 14754 (p. 132).

Mine.—Inez; Inez district; a drift mine in the NW. ¼ sec. 16, T. 33 N., R. 72 W., 1 mile south of Inez and of the Chicago & North Western Railway.

Coal bed.—Not named. Tertiary age, Fort Union formation. Average thickness, about 5 feet; dip, 17° NE.

The bed was measured and sampled by F. A. Herald on September 19, 1912, as described below:

Section of coal bed in Inez mine.

Laboratory No.	14754	
Roof, brown, carbonaceous shale.	*Ft.*	*in.*
Coal	5	3
Shale, carbonaceous, brown	[a]0	5
Shale, gray	[a]0	11
Shale, brown, carbonaceous	[a]0	6
Coal	0	7
Floor, brown, carbonaceous shale.		
Thickness of bed	7	8
Thickness of coal sampled	5	10

[a] Not included in sample.

The sample was taken at the end of the entry, 620 feet northwest of the mouth of the slope.

LOST SPRING. FRED HAYNES PROSPECT.

Sample.—Subbituminous coal; Lost Spring field; analysis No. 10711 (p. 132).

Prospect.—Fred Haynes, a prospect opening in sec. 11, T. 32 N., R. 69 W., 9 miles west of Lost Spring, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—Unnamed. Tertiary age, Fort Union formation. Thickness, 4 feet 2 inches. Roof, shale; floor, shale.

The coal bed was sampled at one point in the entry by D. E. Winchester on August 1, 1910. The sample was taken at the face of the main entry, about 50 feet from the mouth of the entry.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 471, p. 491.

LOST SPRING. HARNEY CREEK MINE.

Sample.—Lignite verging on subbituminous coal; Lost Spring field; analysis No. 10911 (p. 132).

Mine.—Harney Creek, a drift mine in sec. 13, T. 34 N., R. 67 W., 17 miles northeast of Lost Spring, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—Unnamed. Tertiary age, Fort Union formation. Thickness, 5 feet 6 inches. Roof, sandstone; floor, sandstone. The coal bed was sampled at one point in this mine by D. E. Winchester, September 10, 1910, as described below:

Section of coal bed in Harney Creek mine.

Laboratory No.	10911
Roof, sandstone.	*Ft. in.*
Coal	2 10
Shale, carbonaceous	[a]0 1
Coal	2 1
Shale, carbonaceous	[a]0 6
Floor, sandstone.	
Thickness of bed	5 6
Thickness of coal sampled	4 11

[a] Not included in sample.

The above sample was taken at the end of the main entry, 80 feet from the main mouth.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 471, p. 505.

LOST SPRING. ONYON MINE.

Sample.—Subbituminous coal; Lost Spring field; analysis No. 10740 (p. 133).

Mine.—Onyon, a drift mine in sec. 36, T. 33 N., R. 68 W., about 2 miles northwest of Lost Spring, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—Unnamed. Tertiary age, Fort Union formation. Thickness, 5 feet 9 inches; roof, shale; floor, shale.

The bed was sampled at one point in the mine by D. E. Winchester on August 4, 1910. The sample was taken in room 15 off north entry 1, 1,800 feet from the mine mouth.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 471, p. 495.

LOST SPRING. PROSPECT.

Sample.—Subbituminous coal; Lost Spring field; analysis No. 11447 (p. 133).

Prospect.—Prospect in sec. 8, T. 37 N., R. 68 W., 35 miles north of Lost Spring, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—D. Tertiary age, Fort Union formation. Thickness, 4 feet 4 inches; cap, sandstone; floor, shale.

The bed was sampled by D. E. Winchester on October 21, 1910. The bed had been opened as a stripping pit. Some coal had been taken from the prospect during previous winters.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 471, p. 513.

LOST SPRING. ROSIN MINE.

Sample.—Subbituminous coal; Lost Spring field; analysis No. 10775 (p. 133).

Mine.—Rosin, a drift mine in sec. 35, T. 34 N., R. 68 W., 8 miles north of Lost Spring, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—Unnamed. Tertiary age, Fort Union formation. Thickness, 5 feet 1 inch; roof, shale; floor, shale.

The bed was measured and sampled by D. E. Winchester on August 17, 1910, as described below:

Section of coal bed in Rosin mine.

Laboratory No	10775	
Roof, shale.	*Ft.*	*in.*
Coal, soft and bright	1	1
Shale, soft, carbonaceous	[a] 0	3
Coal, bright and hard	1	8
Shale, carbonaceous	[a] 0	1
Coal, bright and hard	2	0
Floor, shale.		
Thickness of bed	5	1
Thickness of coal sampled	4	9

[a] Not included in sample.

The sample was taken at the face of left entry 1 off main entry, about 1,000 feet from the mine mouth.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 471, p. 501.

LOST SPRING. SUNSET MINE.

Sample.—Subbituminous coal; Lost Spring field; analysis No. 10835 (p. 133).

Mine.—Sunset, a drift mine in sec. 35, T. 34 N., R. 68 W., 8 miles northwest of Lost Spring, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—Unnamed. Tertiary age, Fort Union formation. Average thickness about 5 feet; roof, bony coal; floor, shale.

The coal bed was sampled by D. E. Winchester August 20, 1910, as described below:

Section of coal bed in Sunset mine.

Laboratory No	10835	
Roof, bony coal.	*Ft.*	*in.*
Coal	0	4
Bony coal	[a] 1	4
Coal	0	6
Bony coal	[a] 0	½
Coal	0	7
Shale	[a] 0	3
Coal	2	3
Floor, shale.		
Thickness of bed	5	3½
Thickness of coal sampled	3	8

[a] Not included in sample.

This sample was taken at the face of the main entry, 500 feet from the mouth.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 471, p. 502.

CROOK COUNTY.

SUNDANCE. BELSHE MINE.

Sample.—Bituminous coal; Sundance field; analysis Nos. 15713, 15714, and 15715 (p. 133).

Mine.—Belshe; SE. ¼ NW. ¼ sec. 24, T. 51 N., R. 64 W., 7½ miles west of Sundance.

Coal bed.—No name. Lower Cretaceous age, Lakota formation. The bed is nearly horizontal and is variable in thickness and character. Both roof and floor are shale.

The bed was measured and sampled by M. W. Ball on January 2 and 3, 1913, as described below:

Sections of coal bed in Belshe mine.

Section	A		B		C		D	
Laboratory No.	15713				15714 15715			
Roof, section A, black, carbonaceous shale with some coal; section B, black, "slaty" shale; section C, dark-gray shale, "slaty" immediately above coal.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal, somewhat dirty, pyritiferous	0	2	..	..	..	..	..	..
Coal, bright, clean	0	3¾	0	6½	0	2	0	2
Coal, rather dull, but clean	0	2	..	..	..	..	..	..
Coal and pyrite	..	..	0	½	..	..	..	..
Coal, slightly dull, with half inch streaks of lustrous coal	..	..	..	..	0	11¾	..	..
Coal, bright, with a few sulphurous streaks	..	..	..	..	1	1	..	..
Coal, dull	..	..	..	..	0	2	..	..
Coal, bright	1	1	0	5½	0	7	..	..
Coal, moderately bright, rather hard	2	2	..	..	..	..	..	..
Splint and good coal, intermixed	[a] 0	2½	..	..	..	..	..	..
Coal, rather dull	..	..	0	7½	..	..	..	..
Coal, bright	..	..	1	4	..	..	..	..
Coal, rather dull and hard	..	..	0	6¾	..	..	..	..
Coal, good	..	..	..	..	..	..	3	2
Splint	[a] 0	2½	0	5¼	[b] 0	4½	0	2¼
Coal, moderately bright, with a little pyrite	1	0	..	..	..	..	..	..
Coal	..	..	..	..	[b] 0	3	0	7
Splint	..	..	..	..	[b] 0	2	0	1¾
Coal, bright	..	..	0	3	0	6	..	..
Coal, somewhat dull	..	..	0	4	..	..	..	..
Coal	..	..	0	3½	..	..	0	3½
Floor, section A, black shale; section B, "slaty" shale, with some coal; section C, "slaty" shale; section D, dark-gray shale.								
Thickness of bed	5	3¾	4	10½	4	3¼	4	6½
Thickness of coal sampled	4	10¾	4	10½	([c])		4	6½

[a] Not included in sample.
[b] Not included in sample 15714 but included in sample 15715.
[c] Sample 15714, 3 feet 5¾ inches; sample 15715, 4 feet 3¼ inches.

Section A (sample No. 15713) was taken at end of room turned east from back entry, 275 feet from mouth of mine.

Section B was taken at the end of the back entry.

Section C (samples Nos. 15714 and 15715) was taken in the last crosscut, 48 feet from the front entry.

Section D was taken at the end of the front entry.

FREMONT COUNTY.

HUDSON. HICKEY MINE.

Sample.—Subbituminous coal; Hudson field of the Wind River region; analysis No. 17247 (p. 133).

Mine.—Hickey, a slope mine in sec. 11, T. 1 S., R. 2 E., 1 mile west of Hudson and one-fourth of a mile from the main line of the Chicago & North Western Railway.

Coal bed.—Unnamed. Cretaceous age, Mesaverde formation. Average thickness about 3 feet 8 inches; dip 13° E., 15° N. Faults, rolls, and horsebacks are uncommon. Roof, hard gray shale, above which is sandstone cap rock; floor, hard smooth shale; particles of the roof and floor do not get mixed with the coal in mining. The cover at the point where sample was taken is about 100 feet.

The coal bed was measured and sampled by J. C. Roberts on May 16, 1913. The sample included a 3½ foot cut of coal. The roof was shale, over which was sandstone; the floor was shale.

The sample was taken in room 3, off the south entry, 300 feet from the mouth of the mine.

Notes.—The Hickey mine is opened by a slope and the coal is mined by the room-and-pillar system. The coal was undercut by hand and broken down with black blasting powder. The coal cuttings were loaded with the coal. The screening equipment consisted of bar screens 12 feet long with 1½-inch and ½-inch openings. No men were employed to pick shale out of the cars at the tipple. Eight men were employed at the mine.

For a description of the geologic relation of this bed see U. S. Geol. Survey Bull. 471, p. 565.

Hudson. Indian Mine.

Sample. Subbituminous coal: Hudson field; analyses Nos. 10838, 10839, 10840, 10841, 10842, 10843, 13178, and 13179 (p. 133).

Mine. Indian; slope mine near Hudson, in the NE. ¼ sec. 2, T. 2 S., R. 2 E., in the Shoshone Indian Reservation, on a spur of the Wyoming & North Western Railway.

Coal bed. The bed has not been designated by name, because of the lenticular nature of the beds in this region. Cretaceous age; Mesaverde formation. Thickness in the mine, variable; dip, 13° S. where sample 13178 was taken, and 18° S. where sample 13179 was taken.

The bed was measured and sampled at five points on September 3, 1910, by H. M. Wolflin, and at two points on December 11, 1911, by Max A. Pishel, as shown below:

Sections of coal bed in Indian mine.

Section	A		B		C		D		E	
Laboratory No.	10838		10839		10840		10841		10843	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
"Draw slate"	..	..	[a]0	10	[a]0	8	[a]0	8	..	..
Clean coal	7	7½	3	10	..	..	3	1½	..	..
Slaty coal	..	..	[a]0	6½	..	..	..	..	..	..
Bony coal	..	..	..	..	0	7	0	2½	..	..
Clean coal	..	..	2	5	6	7	3	2	7	6
Floor, clay.										
Thickness of bed	7	7½	7	7½	7	10	7	2	7	6
Thickness of coal sampled	7	7½	6	3	7	2	6	6	7	6

Section	F		G	
Laboratory No.	13178		13179	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	6	..	..
Coal, with bony streaks	..	..	0	10
Bone	[a]0	4	[a]0	4
Coal	..	..	2	0
Shale, bony	[a]1	2	[a]1	0
Coal	1	6	0	8
Bone	[a]0	4	[a]0	2
Shale, bony	[a]1	2	..	..
Coal	0	6	2	0
Floor, sandstone.				
Thickness of bed	6	6	7	0
Thickness of coal sampled	3	6	5	6

[a] Not included in sample.

Section A (sample 10838) was measured at the face of room 17, off the 00 entry.

Section B (sample 10839) was measured at the face of west entry 4.

Section C (sample 10840) was measured in a room (about No. 30), off west entry 2.

Section D (sample 10841) was measured at the face of room 4, off east entry 3.

Section E (sample 10843) was measured at the face of room 14½, off west entry 2.

Section F (sample 13178) was measured in the fifth west back entry, one-fourth of a mile southwest of the mine mouth.

Section G (sample 13179) was taken in the main entry, 900 feet from the mine mouth.

A composite sample was made by mixing samples 10838, 10839, 10840, and 10841. The results of an ultimate analysis of this sample are given under laboratory No. 10842.

Notes. At the time of sampling in 1911 the mine had been abandoned several months and a number of men were engaged in removing the hoisting engine. It seemed probable that in the future the mine would be worked on a small scale, as there was still considerable coal left in the mine as pillars. The probable lifetime of the mine was 10 years.

HUDSON. MITCHELL MINE.

Sample.—Subbituminous coal; Hudson field; analysis No. 17248 (p. 133).

Mine.—Mitchell, a slope mine in the Shoshone Indian Reservation, in the SW. ¼ sec. 22, T. 1 S., R. 2 E., 5 miles from Hudson and 3½ miles from the Indian mine spur off the Chicago & North Western Railway.

Coal bed.—The bed has not been designated by name, chiefly because most of the beds in this region are lenticular. Cretaceous age, Mesaverde formation. Average thickness, 3 feet; dip, 20° S. 40° E. No cleats, rolls, or horsebacks have been encountered. Roof, excellent shale, above which is sandstone; floor, hard, smooth shale. The cover at the point where the sample was taken is about 100 feet thick.

The coal bed was measured and sampled at one point in the mine by J. C. Roberts, on May 16, 1913, as described below:

Section of coal bed in Mitchell mine.

Laboratory No	17248
Roof, sandstone over shale.	*Ft. in.*
Coal	1 2
Shale parting	[a]0 1½
Coal	2 ½
Floor, shale.	
Thickness of bed	3 4
Thickness of coal sampled	3 2½

[a] Not included in sample.

The sample was taken in the last room off the main slope, 40 feet from the slope and 500 feet from the mouth of the slope.

Notes.—The Mitchell mine is opened by a slope which is 5,050 feet above sea level. Although the long-wall method of mining was started, the workings at the time of sampling consisted mostly of rooms and gangways. The screening plant consisted of bar screens with 1-inch openings. There were no railway connections and the coal was transported by wagons. The mine was operated only when the operator had an order for coal for local consumption. All workings were advance.

HUDSON. PROPOSIA MINE.

Sample.—Lignite; analyses Nos. 17244, 17245, and 17246 (p. 133).

Mine.—Proposia, a slope mine 4 miles from Hudson on a spur of the Chicago & North Western Railway.

Lignite bed.—Lander. Cretaceous age, Mesaverde formation. Average thickness, 12 feet, ranging from 8 to 17 feet; dip, 14° N. 17° E. There are no cleats, faults, rolls, or horsebacks in the bed. Roof, shale with a sandstone cap rock; floor, hard smooth shale. Particles of the roof and floor do not mix with the coal in mining. The roof at the points where the samples were taken varies from 100 to 300 feet in thickness.

The lignite bed was measured and sampled at two points by J. C. Roberts on May 18, 1913, as described below:

Sections of lignite bed in Proposia mine.

Section	A	B
Laboratory No	17244	17245
Roof, shale under sandstone.	*Ft. in.*	*Ft. in.*
Clean coal	[a]7 6	.. ..
Do	9 6	8 0
Floor, shale.		
Thickness of bed	17 0	8 0
Thickness of coal sampled	9 6	8 0

[a] Not included in sample.

Section A (sample 17244) was measured at the face of the second north entry, 1,800 feet from the mine mouth.

Section B (sample 17245) was measured at the face of the fifth south entry, 1,200 feet from the mine mouth.

A composite sample was made by mixing samples 17244 and 17245. The results of an ultimate analysis of this sample are given under laboratory No. 17246.

Notes.—The Proposia mine is opened by a slope. The coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by hand and shot down with FF black blasting powder. The cuttings were loaded with the coal. None of the coal was shipped as run-of-mine. The screening equipment consisted of shaking screens 32 feet long by 8 feet wide; diameter of holes ½, 2, 4, 5, 6, and 8 inches. Twenty-five per cent of the coal was lump; 30 per cent grate; 33 per cent nut, and 12 per cent slack. One picker was employed on the screens. The lump coal was large and had an excellent appearance on the cars. There were three loading tracks with a capacity for 50 empty cars and 50 loaded cars. There was approximately 600 acres of unmined coal to be taken out. The mine had an estimated life of 10 years. About 75 per cent of the future tonnage was to be derived from advance work and 25 per cent from pillars. The daily output at the time of sampling (May, 1913) was 1,100 tons, with a maximum day's run of 1,300 tons.

HOT SPRINGS COUNTY.

CROSBY. BIG HORN MINE.

Sample.—Subbituminous coal; analyses Nos. 15201 to 15212, 15214 to 15219, 15234 to 15237 (pp. 134–136).

Mine.—Big Horn, a slope mine at Crosby, 2 miles from Kirby, on the Chicago, Burlington & Quincy Railroad.

Coal bed.—Gebo. Cretaceous age, Laramie formation. Thickness of coal, 5 feet 6 inches to 8 feet 6 inches, not including the top coal, which is about 2½ feet thick and is left up for roof; dip, 17° N. 15° E. No faults, rolls, or horsebacks are encountered. Roof, clay and shale with a sandstone cap rock; floor smooth, medium-hard, shaly clay. Neither roof nor floor particles mixed with the coal in mining. Machine cuttings were loaded with the coal. The cover at the points where the samples were taken varies from 85 to 300 feet in thickness.

The coal bed was measured and sampled at five points in the mine and four samples of slack coal were taken, one in the mine and three from wagons, by O. U. Bradley, December 6 to 17, 1912, as described below:

Sections of coal bed in Big Horn mine.

Section	A		B		C		D		E	
Laboratory No.	15201 15202		15209 15210		15214 15215		15216 15217		15218 15219	
Roof, clay and shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	..	..	1	7	..	..	..	..	..	..
Bony coal	..	..	0	1	..	..	..	..	..	..
Coal	7	6	1	0	8	1	2	4	5	3
Bony coal	..	..	[a]0	3	..	..	[a]0	3	..	..
Coal	..	..	5	6	..	..	5	11	..	..
Floor, underclay.										
Thickness of bed	7	6	8	5	8	1	8	6	5	3
Thickness of bed sampled	7	6	8	2	8	1	8	3	5	3

[a] Not included in sample.

Section A (duplicate samples 15201 and 15202) was measured on the east side of room 5, off butt entry 3 off west entry 1.

Section B (duplicate samples 15209 and 15210) was cut from east side of room 5, 50 feet from second butt dip entry off west entry 2.

Section C (duplicate samples 15214 and 15215) was cut from a pillar between rooms 6 and 7, off butt entry 2 off west entry 1.

Section D (duplicate samples 15216 and 15217) was cut from the face of room 6, off first dip butt entry off west entry 2.

Section E (duplicate samples 15218 and 15219) was cut from the face of room 9, off east entry 2, 45 feet from the entry.

A composite sample was made by mixing samples 15205, 15207, and 15211. The results of an ultimate analysis of this sample are shown under laboratory No. 15234.

A composite sample was made by mixing samples 15206, 15208, and 15212. The results of an ultimate analysis of this sample are shown under laboratory No. 15235.

A composite sample was made by mixing samples 15201, 15210, 15216, and 15218- The results of an ultimate analysis of this sample are shown under laboratory No. 15236.

A composite sample was made by mixing samples 15202, 15209, 15217, and 15219. The results of an ultimate analysis of this sample are shown under laboratory No. 15237.

Duplicate samples 15203 and 15204 represent slack coal taken from the mine.

Duplicate samples 15205 and 15206 represent slack from 17 wagonloads averaging 3,400 pounds each.

Duplicate samples 15207 and 15208 represent slack coal taken from 20 wagon-loads averaging 3,400 pounds each.

Duplicate samples 15211 and 15212 represent slack coal taken from 18 wagon-loads averaging 3,400 pounds each.

Notes.—The Big Horn mine is opened by a slope. The coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by three electric coal-cutting machines and four air-punching machines. It was shot down with black blasting powder. Twenty-six per cent of the output passed through the screens. Grades of coal produced were: Lump coal, that passing 3, 4, and 8 inch openings; egg nut, that passing 4-inch to 1¼-inch openings; nut, that passing 3-inch to 1¼ inch openings; pea, that passing 1¼-inch to ⅜-inch openings. About 70 per cent of the coal was shipped under the first three classifications. There was little demand for the pea coal and the excess was thrown in with the slack and run out to the dump, except a small amount burned in the company's boilers. The lumps were large and had a good appearance. There were four loading tracks with a capacity of 15 empty and 15 loaded cars. There was approximately 490 acres to be taken out from the opening. The daily average output was 800 tons, with a maximum day's run of 815 tons.

KIRBY. GEBO MINE.

Sample.—Subbituminous coal; Bighorn Basin field; analyses Nos. 15277, 15278, 15279, 15280, 15281, 15282, 15283, 15342, 15343, 15344, 15345, 135346, 15347, 15348, 15349, 15475, 15482, 15687, and 16102 (pp. 136, 137).

Mine.—Gebo, a slope mine 2 miles southwest of Kirby in the S. ½ sec. 11, T. 44 N., R. 95 W., on a spur of the Chicago, Burlington & Quincy Railroad.

Coal bed.—Gebo. Cretaceous age, Eagle sandstone. Average thickness 10 feet 8 inches, dip 20½° N. 24° E.; cleat N. 57° E. No faults, rolls or horsebacks are encountered. Roof, clay and shale, with a sandstone cap rock; floor, hard and smooth sandstone. Particles of the roof and floor seldom mix with the coal in mining. Machine cuttings were loaded with the coal. The cover at the points where the samples were taken varies from 100 to 410 feet in thickness.

The coal bed was measured and sampled at 10 points in the mine, and 12 samples of slack were taken as it was being loaded on the car by O. U. Bradley, December 13 to 27, 1912, and 2 samples were taken from the cars of slack at Pittsburgh, Pa., by E. R. Linkenhoker on January 15 and 31, 1913, as described below:

Section of coal bed in Gebo mine.

Section	A	
Laboratory No	15277	
Roof, top coal, clay, and shale.	*Ft.*	*in.*
Clean coal	7	2
Coal, slightly bony	0	2
Coal	0	6
Floor, clay.		
Thickness of bed	7	10
Thickness of coal sampled	7	10

Section A (sample 15277) was measured at the face of the fourth east entry, 225 feet from the second butt entry.

Sections B, C, D, E, F, G, H, I, and J were cut as described below. Sections B to E had a roof of top coal, clay, and shale, and a floor of clay; sections F to J had a roof of top coal, clay, "slate," and sandstone, and a floor of clay.

Section B (sample 15278) represented an 8-foot 9-inch cut of coal. It was measured at the face of room 8 east, second butt entry off the fifth entry.

Section C (sample 15279) represented a 9-foot 8-inch cut of coal. It was measured at the face of room 7 east, off first butt entry off the fifth level.

Section D (sample 15280) represented a 9-foot 2-inch cut of coal. It was measured at the face of the third east entry, 400 feet from the second butt entry.

Section E (sample 15281) represented a 7-foot 11-inch cut of coal. It was measured at the face of the third west entry, 300 feet from the main slope.

Section F (sample 15282) represented a 6-foot 9-inch cut of coal. It was measured on a pillar between room 1 west and the back entry off second level.

Section G (duplicate samples 15342 and 15343) represented a 5-foot 9-inch cut of coal. It was measured on a pillar between the second west entry and the back entry, 375 feet beyond the third butt entry, 1,750 feet from main slope.

Section H (duplicate samples 15344 and 15345) represented a 6-foot 1-inch cut of coal. It was measured on a pillar between rooms 1 and 2 west, off the first butt entry off the second east entry, about 400 feet from main slope.

Section I (duplicate samples 15346 and 15347) represented a 6-foot 5-inch cut of coal. It was measured on a pillar between pitch rooms 10 and 11, off the first west entry.

Section J (duplicate samples 15348 and 15349) represented a 6-foot 7-inch cut of coal. It was measured near the face on a pillar between the first west entry and the back entry, 2,100 feet from the slope.

A composite sample was made by mixing samples 15277, 15278, 15279, and 15280. The results of ultimate analysis of this sample are shown under laboratory No. 15283.

A composite sample was made by mixing six separate samples taken from the slack as it was being loaded into the cars for shipment. The results of an ultimate analysis of this sample are given under laboratory No. 15475.

A composite sample was made by mixing six samples taken from the slack as it was being loaded into the cars for shipment. The results of an ultimate analysis of this sample are given under laboratory No. 15482.

Samples were collected from each of two cars of slack shipped to Bureau of Mines, Pittsburgh, Pa., for a test as to most efficient utilization. For the results of analysis, see laboratory Nos. 15687 and 16102.

Notes.—The Gebo mine is opened by a drift. The coal is mined by the room-and-pillar system. At the time of sampling it was undercut by electric chain machines and compressed-air punching machines and was broken down with black blasting powder. The machine cuttings were loaded out with the coal. About 12 per cent of the coal was shipped as run-of-mine. The tipple was equipped with a shaking screen 42 by 7 feet, 15 feet having 1-inch holes, 4 feet, 1¼-inch holes, 4 feet, 2½-inch holes, 4 feet, 5-inch holes, 4 feet, 8-inch holes, and a ⅜-inch screen for slack. No men were employed on the cars or belts to pick shale from the coal. The lumps being loaded were large and had a good appearance. There were four loading tracks with a capacity of 75 empty cars and 75 loaded cars. Approximately 1,000 acres of coal remained to be taken out. The mine was expected to have a lifetime of 50 years; future tonnage was to be derived almost wholly from advance workings. The daily output was 750 tons, with a maximum day's run of 1,026 tons. The daily output was to be increased to 1,000 tons or more.

MEETEETSE. DICKIE NO. 1 PROSPECT.

Sample.—Subbituminous coal; Bighorn Basin field; analysis No. 14679 (p. 137).

Mine.—Dickie No. 1; a prospect drift on the northwest side of Grass Creek Basin, in sec. 2, T. 46 N., R. 99 W., 18 miles southeast of Meeteetse.

Coal bed.—No name. Cretaceous age, Gebo formation (Eagle sandstone). Dip, 16° N.

The bed was measured and sampled by D. F. Hewett, August 23, 1912, as described below:

Section of coal bed in Dickie No. 1 prospect.

Laboratory No.	14679	
Roof, brown shale.	*Ft.*	*in.*
Coal	0	1
Shale	0	½
Coal	0	5
Coal, bony	0	2
Coal	2	6
Shale	0	½
Coal	0	9
Floor, shale.		
Thickness of bed	4	0
Thickness of coal sampled	4	0

The sample was taken from the east rib of the western of two short drifts at a point 25 feet from the mouth. As the mine had been idle since 1910, the coal was weathered.

MEETEETSE. MAYFIELD NO. 2 PROSPECT.

Sample.—Subbituminous coal; Bighorn Basin field; analysis No. 14756 (p. 137).

Mine.—Mayfield No. 2. A prospect 2 miles southwest of Grass Creek Basin, in E. ½ sec. 26, T. 46 N., R. 99 W., 19 miles southeast of Meeteetse.

Coal bed.—No name. Tertiary age, Fort Union formation. Dip 5° SE.

The bed was measured and sampled by D. F. Hewett on August 24, 1912, as described below:

Section of coal bed in Mayfield No. 2 prospect.

Laboratory No.	14756	
Roof, gray shale.	*Ft.*	*in.*
Coal	[a]24	0
Coal, bench sampled and mined	6	0
Floor, sandstone.		
Thickness of bed	30	0
Thickness of coal sampled	6	0

[a] Not included in sample.

The sample was taken at the face of the new drift, 30 feet from the mouth.

Notes.—This prospect was opened in 1911 on the west side of a ravine, 500 feet southwest of an old opening on the east side, where sample No. 5770 was collected by E. G. Woodruff in 1907.

Only the lower part of the bed was mined. The mine was operated only intermittently, but the sample represented unweathered coal.

JOHNSON COUNTY.

BUFFALO. PROSPECT.

Sample.—Subbituminous coal; Sussex field (Basin No. 2); analysis No. 10683 (p. 137).

Mine.—This sample was taken from a small prospect which was being operated by ranchers in sec. 17, T. 47 N., R. 81 W. The mine is 18 miles southeast of Buffalo and about 50 miles south of Regis, which is the nearest station on the Chicago, Burlington & Quincy Railroad

Coal bed. [illegible]. Tertiary age, Fort Union formation. Thickness, about [illegible] feet; sandstone capping.

The bed was measured and sampled by C. H. Wegemann on July [illegible], 1910, as described below:

Section of coal bed in prospect [illegible] miles southeast of [illegible].

Laboratory No.	[illegible]	
Roof, [illegible] sandstone.	*Ft.*	*in.*
Coal	a1	4
Shale [illegible]	a2	1
Coal	a2	[illegible]
Shale	a1	[illegible]
Coal	[illegible]	4
Shale	a1	[illegible]
Coal	a2	[illegible]
Floor, not reached.		
Thickness of bed	[illegible]	[illegible]
Thickness of coal sampled	[illegible]	4

a Not included in sample.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. [illegible], p. [illegible].

CASPER. PROSPECT.

Sample. Subbituminous coal; Sussex field (Basin No. 4); analysis No. [illegible] (p. [illegible]).

Mine. Prospect in sec. [illegible], T. 44 N., R. [illegible] W., about 75 miles north of Casper, which is the nearest station on the Chicago & North Western Railway.

Coal bed. Unnamed. Tertiary age, Fort Union formation. Thickness 6 feet 3 inches; cap rock, sandstone.

The coal bed was sampled by C. H. Wegemann on July 29, 1910, as described below:

Section of coal bed in prospect, 75 miles north of Casper.

Laboratory No.	[illegible]	
Roof, sandstone.	*Ft.*	*in.*
Shale	a0	6
Coal	3	7
Coal, bony	a0	2
Coal	a2	0
Floor, not reached.		
Thickness of bed	6	3
Thickness of coal sampled	3	7

a Not included in sample.

Note. Coal had been mined at this prospect to some extent for local use.

For a description of the geologic relations of this coal bed, see U. S. Geol. Survey Bull. 471, p. 458.

CASPER. PROSPECT.

Sample. Subbituminous coal; Sussex field (Basin No. 4); analysis No. 10804 (p. 137).

Mine. Prospect in sec. 36, T. 43 N., R. 79 W., about 60 miles north of Casper, which is the nearest station on the Chicago & North Western Railway.

Coal bed. Unnamed. Tertiary age, Fort Union formation. Thickness, about 14 feet. It was sampled by C. H. Wegemann, August 16, 1910, as described below:

Section of coal bed in prospect, about 60 miles north of Casper.

Laboratory No.	10804	
Roof, not stated.	*Ft.*	*in.*
Shale	[a]0	6
Coal	[a]0	8
Shale	[a]1	2
Coal	2	5
Coal, bony	[a]0	5
Coal	1	2
Shale	[a]0	6
Coal	[a]1	1
Shale	[a]1	0
Coal	[a]1	2
Coal, bony	[a]0	7
Coal	[a]2	3
Floor, not stated.		
Thickness of bed	12	11
Thickness of coal sampled	3	7

[a] Not included in sample.

For a description of the geologic relations of this bed, see U. S. Geol. Survey Bull. 471, p. 462.

CASPER. PUGGSLEY MINE.

Sample.—Subbituminous coal; Sussex field (Basin No. 4); analysis No. 10827 (p. 138).

Mine.—Puggsley, a mine in sec. 20, T. 42 N., R. 77 W., 65 miles north of Casper, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—Unnamed. Tertiary age, Fort Union formation. Thickness, 20 feet 5 inches. It was sampled at one point in this mine by Carroll H. Wegemann, on August 26, 1910, as described below:

Section of coal bed in Puggsley mine.

Laboratory No.	10827	
Roof, not stated.	*Ft.*	*in.*
Coal	[a]0	10
Bone	[a]0	4
Coal	[a]3	0
Shale and coal	[a]1	10
Coal	5	0
Coal, bony	[a]0	3
Coal	[a]0	8
Bone	[a]0	7
Coal	[a]4	2
Shale	[a]0	3
Coal	[a]3	6
Floor, not stated.		
Thickness of bed	20	5
Thickness of coal sampled	5	0

[a] Not included in sample.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 471, 1912, p. 461.

CASPER. PROSPECT.

Sample.—Subbituminous coal; Sussex field; analysis No. 11059 (p. 138).

Mine.—Prospect in sec. 32, T. 41 N., R. 78 W., 50 miles north of Casper, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—Unnamed. Tertiary age, Fort Union (?) formation. Bed, 3 feet 10 inches thick, with a sandstone cap rock 12 feet thick, and a sandstone floor. The coal bed was sampled by C. J. Hares on October 6, 1910, as described below:

Section of coal bed in prospect, 50 miles north of Casper.

Laboratory No.	11059	
Roof, sandstone.	*Ft.*	*In.*
Coal	2	2
Sandstone	[a]0	8
Shale	[a]1	0
Floor sandstone.		
Thickness of bed	3	10
Thickness of coal sampled	2	2

[a] Not included in sample.

Note.—The coal had been mined to some extent for local use.

KAYCEE. ABANDONED MINE.

Sample.—Bituminous coal; Sussex field (Basin No. 3); analysis No. 10694 (p. 138).

Mine.—An abandoned mine in sec. 24, T. 44 N., R. 81 W., 6 miles northeast of Kaycee and about 50 miles north of Bucknum, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—Unnamed. Cretaceous age, Fort Union formation.

The bed was sampled at one point in the mine by O. B. Hopkins. The sample represented the entire face section of the coal bed.

For a description of the geologic relations of this coal bed see U. S. Geol. Survey Bull. 471, 1912, p. 459.

NATRONA COUNTY

CASPER. RED ASH MINE.

Sample.—Subbituminous coal; Wind River field; analysis No. 10671 (p. 138).

Mine.—Red Ash, a drift mine in sec. 14, T. 31 N., R. 82 W., Platte River district, about 25 miles southwest of Casper, which is the nearest station on the Chicago & North Western Railway.

Coal bed.—Not named. Cretaceous age, Fort Union formation. Thickness, 6 feet 3 inches. The bed is overlain with 4 inches of carbonaceous shale capped by sandstone; floor, carbonaceous shale.

The bed was sampled at one point in the mine by D. E. Winchester on July 9, 1910. The sample was taken at the face of the second and last room off the main entry, about 300 feet from the mine mouth.

Note.—The mine had been worked periodically to supply local use, but was idle at the time of sampling.

PARK COUNTY.

CODY. McGUFFEY MINE.

Sample.—Subbituminous coal; Bighorn Basin field; analysis No. 12886 (p. 138).

Mine.—McGuffey; a slope mine on the north side of Oregon Basin, in sec. 17, T. 52 N., R. 100 W., 9 miles southeast of Cody.

Coal bed.—Unnamed. Cretaceous age; Gebo formation (Eagle sandstone). Dip, 14° NE.

The bed was measured and sampled by D. F. Hewett on August 18, 1911, as shown below:

Section of coal bed in the McGuffey mine.

Laboratory No.	12886	
Roof, blue shale.	*Ft.*	*in.*
Coal	0	5
Coal, high in pyrite	0	1
Coal	0	7
Shale	[a] 0	5
Coal	1	7
Floor, shale.		
Thickness of bed	3	1
Thickness of coal sampled	2	8

[a] Not included in sample.

The sample was taken from the east rib of a room 20 feet above entry 3, at a point 70 feet east of the slope. The coal was unweathered.

Note.—The mine had been opened in 1910 and operated throughout the year.

MEETEETSE. BLACK DIAMOND MINE.

Sample.—Subbituminous coal; Bighorn Basin field; analysis No. 12887 (p. 138).

Mine.—Black Diamond; a slope mine in sec. 21, T. 49 N., R. 100 W., 4 miles north of Meeteetse.

Coal bed.—No name. Tertiary age, Fort Union formation. Thickness, 42 inches; roof, sandstone overlain with shale; floor, shale; dip, 18° NE.

The bed was measured and sampled by D. F. Hewett on September 11, 1911. The sample represented 3½ feet of coal, including the entire bed.

The sample was taken from the breast of a room 30 feet above entry 6, at a point 200 feet west of the slope.

Note.—This is the same mine sampled by E. G. Woodruff in 1907 (No. 5768). Under No. 5768 the location is incorrectly given as sec. 28, T. 49 N., R. 100 W. The mine was operated throughout the year.

MEETEETSE. GREYBULL OR WILSON MINE.

Sample.—Subbituminous coal; Bighorn Basin field; analysis No. 12888 (p. 138).

Mine.—Greybull or Wilson; a slope mine in the SE. ¼ sec. 13, T. 48 N., R. 101 W., 3½ miles southwest of Meeteetse and 40 miles south of Cody.

Coal bed.—No name. Cretaceous age, Gebo formation (Eagle sandstone). Dip, 5° NE.; thickness, 5½ to 6 feet.

The bed was measured and sampled by D. F. Hewett on September 12, 1911, as shown below:

Section of coal bed in Greybull or Wilson mine.

Laboratory No.	12888	
Roof, sandstone.	*Ft.*	*in.*
Coal	[a] 0	6
Shale	[a] 0	3
Coal	2	1
Shale	[a] 0	4
Coal	2	5
Floor, shale.		
Thickness of bed	5	7
Thickness of coal sampled	4	6

[a] Not included in sample.

The sample was taken from the face of a room 200 feet northwest of the slope, at a point 400 feet from the mine mouth.

Notes.—This mine lies on the north side of Greybull River and adjoins the Erskine mine, sampled by E. G. Woodruff in 1907 (sample No. 5769). The Erskine mine and the Wilson mine operate the same bed, though the coal sections in the respective mines differ considerably. The mine was operated throughout the year.

WILEY. EAGLE MINE.

Sample.—Subbituminous coal; Bighorn Basin field; analysis No. 12885 (p. 139).

Mine.—Eagle. A slope mine east of Oregon Basin, in the SW. ¼ sec. [illegible], T. 51 N., R. [illegible], 2 miles northeast of Wiley, 13 miles southeast of Cody.

Coal bed.—No name. Cretaceous age, Mesaverde formation. Dip, 30° E.

The bed was measured and sampled by D. F. Hewett on August 14, 1911, as shown below.

Section of coal bed in Eagle mine.

Laboratory No.	12885
Roof, gray shale.	Ft. in.
Coal	0 4
Coal, bony	1 0
Shale	*a*0 1
Coal	1 11
Shale	*a*0 2
Coal	2 2
Floor, gray shale.	
Thickness of bed	5 8
Thickness of coal sampled	5 5

a Not included in sample.

The sample was taken from the west rib of the north entry, 6 feet from the bottom of the shaft. The coal was unweathered.

Note.—The mine had been idle since 1910.

WILEY. EAST WILEY MINE.

Sample.—Subbituminous coal; Bighorn Basin field; analysis No. 12884 (p. 139).

Mine.—East Wiley, a slope mine on the east side of Oregon Basin, in the SE. ¼ sec. 10, T. 51 N., R. 100 W., 6 miles east of Wiley and 14 miles southeast of Cody.

Coal bed.—No name. Cretaceous age, Gebo (Eagle sandstone) formation. Dip, 22° E. *Roof*, shale; *floor*, brown shale on massive sandstone.

The bed was measured and sampled by D. F. Hewett on August 14, 1911, as shown below.

Section of coal bed in East Wiley mine.

Laboratory No.	12884
Roof, shale.	Ft. in.
Coal	1 6
Shale	*a*0 5
Coal	2 1
Floor, brown shale on massive sandstone.	
Thickness of bed	4 0
Thickness of coal sampled	3 7

a Not included in sample.

The sample was taken from the south rib of the slope at a point 180 feet from the mouth. The coal was unweathered.

Notes.—This mine was sampled by E. G. Woodruff in 1907 (sample No. 5762). The several benches of the bed vary greatly in thickness in the workings, but the total thickness of the bed is nearly uniform. The mine was operated intermittently.

WILEY. WEST WILEY (THOMPSON) MINE.

Sample.—Subbituminous coal; Bighorn Basin field; analysis No. 12883 (p. 139).

Mine.—West Wiley. A drift mine on the southwest side of the Oregon Basin, in sec. 34, T. 51 N., R. 101 W., 4 miles southwest of Wiley and 15 miles southeast of Cody. Operated intermittently.

Coal bed.—No name. Cretaceous age; Gebo (Eagle sandstone) formation. Dip, 28° SW.

The bed was measured and sampled by D. F. Hewett, June 30, 1911, as shown below:

Section of coal bed in West Wiley mine.

Laboratory No.	12883	
Roof, shale.	*Ft.*	*in.*
Coal, bony	[a]0	9
Shale	[a]0	4
Coal, bony	[a]0	4
Coal	1	7
Shale	[a]0	3
Coal	1	8
Shale, black, soft	[a]0	4
Coal, extremely variable	[a]0	4
Floor, sandstone.		
Thickness of bed	5	7
Thickness of coal sampled	3	3

[a] Not included in sample.

The sample was taken from the face of a room 300 feet from the mouth of the drift at a point 40 feet below the surface. The coal was unweathered.

Notes.—This mine was sampled by E. G. Woodruff in 1907 (sample No. 5767), but at the time of sampling the slope had been abandoned and the coal was mined from a drift. The several benches of the bed vary greatly in thickness throughout the workings, the total thickness varying from 4 feet 4 inches to 6 feet.

SHERIDAN COUNTY.

ACME. ACME NO. 1 MINE.

Sample.—Subbituminous coal, Sheridan field; analyses Nos. 10823, 10824, 10826, and 12687 (p. 139).

Mine.—Acme No. 1, a drift mine at Acme, in the SE. ¼ sec. 13, T. 57 N., R. 85 W., on the main line of the Chicago, Burlington & Quincy Railroad.

Coal bed.—Carney. Tertiary age, Fort Union formation. Average thickness, 16 feet; dip, 1° SE.; roof, soft shale or soapstone; floor, shaly clay, fairly hard.

The bed was measured and sampled at three points by H. M. Wolflin, on August 29, 1910, and at one point by O. B. Hopkins, September 30, 1911, as described below:

Sections of coal bed in Acme No. 1 mine.

Section	A		B		C		D	
Laboratory No.	10823		10824		10826		12687	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Dirty coal	..	..	..	..	[a]0	10	..	..
Soft gray shale	..	..	..	..	[a]1	0	..	..
Coal	..	..	..	..	..	..	[a]4	0
Coal and shale	..	..	..	..	[a]0	2	..	..
Shale	..	..	..	..	..	..	[a]1	3
Coal	..	..	..	..	7	7½	8	0
Gray shale	[a]0	10	[a]1	0	[a]0	5	[a]0	7
Bony coal	..	..	[a]0	4	..	..	..	..
Bottom coal, clean	6	2	6	10	[a]7	0	[a]7	0
Floor, clay.								
Thickness of bed	7	0	8	2	17	½	20	10
Thickness of coal sampled	6	2	6	10	7	7½	8	0

[a] Not included in sample.

Section A (sample 10823) was measured on the pillar of room 9 off east entry 5, off the main entry. The sample was from the bottom coal.

Section B (sample 10824) was measured on the pillar of room 1, off west entry 3, off the main north entry, and represented bottom coal.

Section C (sample 10826) was measured on the pillar near the face of west entry 3, off the main north entry; it represented top coal.

The point of measurement of section D was not recorded.

Notes.—The room-and-pillar system of mining was used. At the time of sampling black powder was used for breaking the coal when undercut and for brushing the top and taking up the bottom. None of the coal was shipped as run-of-mine. It was all passed over bar screens set 1½, 3, 4, and 5 inches apart. The screenings from the bar screens passed through revolving screens with openings of 1 and 2 inches. The coal was clean and free from rock but had a tendency to slack. There was only one loading track, with a capacity of 30 cars. The output of the mine was 350 tons per day.

ACME. ACME NO. 2 MINE.

Sample.—Subbituminous coal; Sheridan field; analyses Nos. 10807, 10808, 10809, 10811, and 12683 (p. 139).

Mine.—Acme No. 2, a drift mine at Acme, in sec. 13, T. 57 N., R. 85 W., on the main line of the Chicago, Burlington & Quincy Railroad.

Coal beds.—Carney and Masters. Tertiary age, Fort Union formation. Total thickness of Carney bed, 8 feet; thickness of workable portion, 6 feet; dip, 1° southwest; thickness of Masters bed, 7 to 9 feet. Roof, Carney bed, soft shale above roof coal; followed by soft sandstone; Masters bed, shale. Floor, Carney bed, black shaly clay; Masters bed, shale.

The Carney bed was measured and sampled at four points in the mine by H. M, Wolflin, on August 24, 1910, as described below:

Sections of Carney bed in Acme No. 2 mine.

Section	A		B		C		D	
Laboratory No	10807		10808		10809		10811	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Roof coal	..	..	..	..	..	..	..	..
Clean coal	2	10	2	8	2	6	2	8
Woody coal	1	4	1	4	1	4	1	2
Clean coal	2	2	2	2	2	3½	2	8½
Floor, black shaly clay.								
Thickness of bed	6	4	6	2	6	1½	6	6½
Thickness of coal sampled	6	4	6	2	6	1½	6	6½

Section A (sample 10807) was measured at the face of room 13 off south entry 2 off west entry 3.

Section B (sample 10808) was measured at the face of south entry 5 off west entry 3.

Section C (sample 10809) was measured at the face of room 1 off north entry 1 off west entry 5.

Section D (sample 10811) was measured on a pillar of west entry 1.

The Masters bed was measured and sampled on September 30, 1911, by O. B. Hopkins, as described below:

Section of Masters bed in Acme No. 2 mine.

Laboratory No	12683	
Roof, shale.	*Ft.*	*in.*
Coal	[a] 1	6
Coal	7	0
Floor, shale.		
Thickness of bed	8	6
Thickness of coal sampled	7	0

[a] Not included in sample.

Sample 12683 was taken 2,000 feet northeast of the mine mouth.

Notes.—The coal is subbituminous merging into lignite. About 48 per cent of the output was shipped as run-of-mine. About 10 per cent was disposed of as screenings. The screening plant was the same one described under Acme No. 1 mine. The room-and-pillar system of mining was used; 60 per cent of the coal was produced from advance workings. The ultimate recovery was expected to be 90 per cent. Black powder was used for breaking down the coal, brushing the top, and taking up the bottom.

CARNEYVILLE. CARNEY MINES.

Samples.—Subbituminous coal, Sheridan field; analyses Nos. 12684, 15677, 15678, 15679, 15680, 15681, 15682, 15683, 15684, 15685, and 15686 (pp. 140, 141).

Mines.—Carney, two drift mines north of Carneyville, in secs. 16 and 17, T. 57 N., R. 84 W., on the Chicago, Burlington & Quincy Railroad.

Coal bed.—Known as the Carney. Tertiary age; Fort Union formation. Thickness, fairly uniform, ranging from 16 to 18 feet, 10 to 12 feet of which is mined. Dip, 1° to 2° SE. The coal is mined to a clay parting 1½ to 6 inches thick; in some places it is rather soft and in falling becomes mixed with the coal. Above the parting is 4 to 4½ feet of coal of good grade; it makes an excellent roof and no timbering is required in the rooms or entries. Above this roof coal there is 1 foot to 1 foot 2 inches of clay shale which falls easily. Floor, rather smooth, soft underclay. In places a streak of bony coal 2 to 6 inches thick appears at the bottom of the coal bed next to the underclay. Where this streak was present the undercutting was done above it. The cover ranges from 200 to 225 feet.

The bed was measured and sampled at one point by O. B. Hopkins, on October 4, 1911, as described below:

Section of coal bed in Carney mine.

Laboratory No.	12684	
	Ft.	*in.*
Coal	[a] 5	0
Shale	[a] 1	0
Coal	10	0
Thickness of bed	16	0
Thickness of coal sampled	10	0

[a] Not included in sample.

The section (sample 12684) was measured 1,000 feet northwest of the mine mouth.

The coal bed was also measured and sampled at four points in No. 1 mine and five points in No. 2 mine by O. U. Bradley on January 1 to 9, 1913, as described below:

Section A (sample 15677) was measured at the face of room 10, off north entry 4, off east entry 2. The sample represented a 10-foot 6-inch cut of coal.

Section B (sample 15678) was measured 25 feet in room 9, north entry 2, off west entry 4. The sample represented an 11-foot 2-inch cut of coal.

Section C (sample 15679) was measured at the face of the main entry. The sample represented a 10-foot 10-inch cut of coal.

Section D (sample 15680) was measured at the face of room 12, off north entry 4, off west entry 3, 75 feet from north entry 4. The sample represented a 10-foot 1-inch cut of coal.

These samples were from No. 1 mine; those from No. 2 mine follow.

Section A (sample 15681) was measured at the face of room 5, off north entry 2, off west entry 2. The sample represented an 11-foot 10-inch cut of coal.

Section B (sample 15682) was measured 85 feet in room 16 at face, off north entry 3, off east entry 1. The sample represented an 11-foot 1-inch cut of coal.

Section C (sample 15683) was measured 125 feet in room 15 at face, off north entry 2, off east entry 2. The sample represented an 10-foot 11-inch cut of coal.

Section D (sample 15684) was measured at the face of the main north entry. The sample represented an 11-foot 7-inch cut of coal.

Section E (sample 15685) was measured 65 feet in room 9 at face, off north entry 4, off west entry 1. The sample represented a 10-foot 5-inch cut of coal.

A composite sample was made by mixing samples 15677, 15678, 15679, 15680, 15681, 15682, 15683, 15684, and 15685. The results of an ultimate analysis of this sample are given under laboratory No. 15686.

Notes.—The coal was mined by the panel method, room-and-pillar system. At the time of sampling the coal was undercut by chain breast machines in the bottom part of the bed and shot down with black powder. One wooden tipple was in constant use at the mines and a new steel tipple had been built as a reserve when heavy orders were received. About 22 per cent of the coal was shipped in run-of-mine form, and about 68 per cent passed through the screens. The wooden tipple had bar screens 7 feet long, 3½ feet wide, with 5½-inch spaces; shaker screen, 7½ feet by 8 feet, with holes 2½ inches in diameter, and a revolving screen 28 feet long divided into two sizes, as follows: 12 feet with 1-inch holes and 16 feet with ½-inch holes. No pickers were employed. The tipple was rather high, and the coal fell such a distance in screening that an unusually large percentage of fine coal was produced. All slack coal, which at times included all sizes below 1¼ inches, was loaded direct into box or flat cars, hauled out, and dumped. During certain months of the year, when demand for the fine coal was small, this waste amounted to 2,000 to 3,000 tons per month. The loaded lumps were medium large and had a good appearance on the cars. Three loading tracks were available, with a capacity of 160 loaded and 160 empty cars. About 1,800 acres remained to be mined. Average daily output, 1,800 tons, with a maximum day's run of 2,200 tons.

DIETZ. DIETZ No. 4 MINE.

Sample.—Subbituminous coal; Powder River field; analyses Nos. 16221, 16222, 16223, 16224, 16225, 16226, 16227, 16228, 13498, 13499, 13537 (p. 141).

Mine.—Dietz No. 4, a slope mine in sec. 34, T. 57 N., R. 84 W., at Dietz, on the main line of the Chicago, Burlington & Quincy Railroad.

Coal bed.—Dietz No. 2 (?). Tertiary age, Fort Union formation. Average thickness, 8 feet. The bed is practically horizontal, and very few faults, rolls, or horsebacks are encountered. Roof, bony coal about 6 inches thick, overlain by gray shale. The floor is a shaly clay, and in many places is wet and soft, and particles of it mix with the coal in loading. The cover at the points where the samples were taken varies from 100 to 220 feet in thickness.

The coal bed was measured and sampled at two points in the mine by H. M. Wolflin, January 12, 1912, as described below:

Sections of coal bed in Dietz No. 4 mine.

Section	A		B	
Laboratory No.	13498		13499	
Roof, coal and shale.	*Ft.*	*in.*	*Ft.*	*in.*
Clean coal	2	10	3	9
Bony coal	0	1	0	2
Clean coal	5	6½	3	9
Floor, shaly clay.				
Thickness of coal mined	8	5½	7	8
Thickness of bed sampled	8	5½	7	8

Section A (sample 13498) was measured at the face of room 3, off west entry 4.

Section B (sample 13499) was measured at the face of room 1, off west entry 12, off the main north entry.

A composite sample was made by mixing face samples 13498 and 13499; the results of an ultimate analysis of this sample are shown under laboratory No. 13537.

The bed was also measured and sampled at seven points in the mine by O. U. Bradley, January 31 to February 3, 1913, as described below:

Section A (sample 16221) was measured at the face of room 9, off west entry 6 off north entry 6. The sample represented a 7½ foot cut of coal, the thickness of the coal mined.

Section B (sample 16222) was measured at the face of room 2, off west entry 12 off north entry 4. The sample represented a 7-foot 7-inch cut of coal, the thickness of the coal mined.

Section C (sample 16223) was measured at the face of north entry 4 off west entry 4. The sample represented a 7½-foot cut of coal, the thickness of the coal mined.

Section D (sample 16224) was measured at the face of room 10, off east entry 5 off the main north entry. The sample represented a 7-foot 5-inch cut of coal, the thickness of the coal mined.

Section E (sample 16225) was measured at the face of the main north entry. The sample represented a 7-foot 1-inch cut of coal, the thickness of the coal mined.

Section F (sample 16226) was measured on pillar in room 9, off east entry 14. The sample represented an 8-foot 7-inch cut of coal, the thickness of the coal mined.

Section G (sample 16227) was measured at the face of main entry, 150 feet from opening. The sample represented a 6-foot 1-inch cut of coal, the thickness of the coal mined.

A composite sample was made by mixing the pillar and face samples 16221 to 16227, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 16228.

Notes.—The Dietz No. 4 mine is opened by a slope. At the time of sampling the coal was mined by the double-entry room-and-pillar system. Part of the coal was undercut by hand and part was shot off the solid. The cuttings from mining were loaded with the coal. The coal was shot down with black blasting powder. The screening plant consisted of shaker screens as follows: Screen 6 by 8 feet with 7-inch holes; screens 2½ by 8 feet with 2½-inch holes, 3½ by 8 feet with 2-inch holes; 6 by 8 feet with 1¼-inch holes; and 25 by 8 feet with ¾-inch holes. None of the coal was shipped in run-of-mine form. No pickers were employed. The lump coal had a firm and fairly clean appearance on the cars and was medium large. The coal screenings were fairly clean and well sized. There were five loading tracks with a capacity of 48 empty cars and 48 or more loaded cars. The mine had a probable lifetime of about six years; the tonnage was to be derived from both advance and pillar work. The daily output of the mine was 1,000 tons, with a maximum day's run of 1,500 tons; 1,000 tons was about the capacity of the plant.

KOOI. HUGHEY PROSPECT.

Sample.—Subbituminous coal; Sheridan field; analysis No. 12642 (p. 141).

Prospect.—Hughey; sec. 27, T. 57 N., R. 85 W., 1½ miles south of Kooi.

Coal bed.—Monarch (?). Tertiary age, Fort Union formation. Roof and floor, shale. The bed was measured and sampled by O. B. Hopkins on September 11, 1911. The sample represented a 4-foot cut of coal, the thickness of the bed.

KOOI. KOOI MINE.

Sample.—Subbituminous coal; Sheridan field; analyses Nos. 10818, 10819, 10820, 10821, 12641, 16060, 16061, 16062, 16063, 16064, 16065, 16066, and 16067 (pp. 141, 142).

Mine.—Kooi; a slope mine in sec. 23, T. 57 N., R. 85 W.; at Kooi on a branch of the Chicago, Burlington & Quincy Railroad, about three-fourths of a mile from the main line.

Coal bed.—Known as the Monarch. Average thickness of the coal as mined, 8 feet 6 inches. The bed dips 1° S. 4° E. with a pronounced east-and-west cleat. The roof is coal of variable thickness; above the roof coal is a thick bed of alternate coal and [illegible] The [illegible] at the points where the samples were taken [illegible] 30 to 200 feet.

[illegible] by H. M. Wolflin, on August 26, [illegible] September [illegible], 191[illegible], as described below:

[illegible]

[illegible]

[illegible] of west entry 5 off [illegible]

[illegible] the main air course which [illegible]

[illegible] of west entry 7.

[illegible] of east entry 5 [illegible]

[illegible] east entry 2,100 feet from the mine [illegible]

[illegible] Bradley on January [illegible]

[illegible]

[illegible]

[illegible] of the fifth east entry, [illegible]

[illegible] room 3, of the fifth east entry, [illegible]

[illegible] the fifth east entry, 1,900 feet [illegible]

[illegible] eleventh east entry, [illegible]

[illegible] room 4, of tenth east entry, [illegible]

[illegible] of tenth east entry, [illegible]

Section G (sample 16066) was measured at the face of the twelfth west entry, 185 feet from main slope.

A composite sample was made by mixing the face samples 16060 to 16066, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 16067.

Notes.—The Kooi mine is opened by a slope 3,550 feet above sea level and is worked by the room-and-pillar panel system. At the time of sampling the coal was undercut by puncher and electric chain breast machines and broken down with black blasting powder. The machine cuttings were loaded with the coal. The screening plant consisted of shaking screens 6 by 8 feet with 6-inch openings, 6 by 9 feet with 2½-inch openings, 6 by 7 feet with 1¼-inch openings, and 6 by 7 feet with ¾-inch openings. Thirty per cent of the coal passed over the 6-inch screen. The lumps on the car were large and had a good appearance. There were five loading tracks with a capacity of 60 empty cars and 60 loaded cars. Twenty-seven per cent of the coal was shipped in run-of-mine form. Estimated probable life of the mine, 15 to 20 years. The estimated average output at time of sampling was 1,000 tons a day; maximum day's run 1,600 tons.

MONARCH. MONARCH MINES.

Sample.—Subbituminous coal; Sheridan field; analyses Nos. 12005, 12006, 12008, 12685, 15830, 15831, 15832, 15833, 15834, 15835, 35836, and 15837 (p. 143).

Mines.—Monarch and New Monarch, drift mines. The Monarch is at Monarch and the New Monarch is in the SE. ¼ sec. 24, T. 57 N., R. 85 W., west of Monarch, with railroad connections to the main line of the Chicago, Burlington & Quincy Railroad.

Coal bed.—Monarch. Tertiary age, Fort Union formation. Average thickness, 30 feet, about 10 feet of which is mined. The bed dips slightly to the southeast. The upper part of the bed consists of coal mixed with bands of shale which are nonpersistent; mining is confined to the lower part. Floor, dark-gray underclay which becomes very soft and swells when wet. The Carney bed is 90 feet below the Monarch. The cover at the points where samples were taken ranges from 40 to 300 feet.

The bed was measured and sampled at three points in the old mine by H. M. Wolflin, on March 29, 1911; and at one point in the new mine by O. B. Hopkins, on October 4, 1911.

Sections of coal bed in Monarch mines.

Section	A		B		C		D	
Laboratory No	12005		12006		12008		12685	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	..	..	..	..	..	..	[a]6	0
Shale	..	..	..	..	..	..	[a]3	0
Coal	..	..	..	..	..	..	[a]6	0
Clean bright coal	7	10	5	4	8	2	10	0
Dull hard coal	..	..	0	9	..	..	..	..
Clean bright coal	..	..	2	1	..	..	..	..
Floor, underclay.								
Thickness of coal sampled	7	10	8	2	8	2	10	0

[a] Not included in sample.

Section A (sample 12005) was measured on the pillar of butt entry 3, off west entry 9, near room 70.

Section B (sample 12006) was measured at the face of room 70, near west entry 7.

Section C (sample 12008) was measured on a pillar in west entry 9, near room 70.

Section D (sample 12685) was measured 800 feet southwest of the mine mouth.

The bed was also measured and sampled at seven points in the new mine by O. U. Bradley on January 11 to 17, 1913, as described below:

Section A (sample 15830) was measured at the face of east entry 6, 250 feet from main haulage slope. The sample represented a 9-foot 2-inch cut of clean coal.

Section B (sample 15831) was measured at the face of west entry 8.

Section C (sample 15832) was measured at the face of west entry 13, off old slope. The sample represented an 8-foot 11-inch cut of clean coal.

Section D (sample 15833) was measured in west entry 4, opposite butts 5 and 6, 800 feet from haulage way. The sample represented a 10-foot 1-inch cut of clean coal.

Section E (sample 15834) was measured at the face of room 8, off butt entry 4, off west entry 4. The sample represented a 10-foot 4-inch cut of clean coal.

Section F (sample 15835) was measured on a pillar between rooms 24 and 25, off west entry 12. The sample represented a 9-foot cut of clean coal.

Section G (sample 15836) was measured on a pillar between rooms 5 and 6, off butt entry 2, off west entry 3. The sample represented a 9-foot 9-inch cut of clean coal.

A composite sample was made by mixing samples 15830 to 15836, inclusive. The results of an ultimate analysis of this sample are given under laboratory No. 15837.

Notes.—The Monarch mine is opened by a drift and the coal is mined by the double-entry room-and-pillar panel system. At the time of sampling the coal was undercut by electric chain coal-cutting machines and broken down with FF black powder. Machine cuttings were loaded out with the coal. No impurities mixed with the coal in loading. About one-third of the coal was shipped as run-of-mine and about 68 per cent of the remainder passed through the screens. The tipple was equipped with bar screens, one 12 feet long with 5-inch openings, one 12 feet long with 4-inch openings, and shaker screens, one 12 by 6 feet with 2½ and 1½ inch openings, and one 12 feet long with 1-inch openings. No pickers were employed on the cars. The mine had a storage bin with a capacity of 280 tons. The lumps and slack appeared fairly good on the cars. Eight loading tracks were available with a capacity of 100 empty and 100 loaded cars. Fifty per cent of the coal mined was from advance workings. The mine had approximately 300 acres unmined. Average daily ouput, 1,600 tons.

NEW ACME. NEW ACME MINE.

Sample.—Subbituminous coal; Sheridan field; analyses Nos. 16055, 16056, 16057, 16058, and 16059 (p. 143).

Mine.—New Acme, a drift mine in sec. 22, T. 57 N., R. 84 W., at New Acme, on a spur of the Chicago, Burlington & Quincy Railway, three-fourths of a mile from the main line.

Coal bed.—Known as the Monarch. Tertiary (Eocene) age, Fort Union formation. The thickness of the coal bed ranges from 16 to 30 feet, of which 6½ to 10 feet is mined. Coal was left for roof as the overlying strata was weak. Many fires originated in the roof coal, particularly when the pillars were being pulled. The floor was coal in all places examined or sampled. The floor of the Monarch seam as exposed elsewhere is composed chiefly of dark carbonaceous shale and squeezes and swells when wet.

There is about 50 to 100 feet of cover at the points where the samples were collected.

The coal bed was measured and sampled at four points in the mine on January 20 and 21, 1913, by O. U. Bradley, as described below:

Section A (sample 16055) was measured at the face of west entry 7, 150 feet from the main slope. The sample represented a 6-foot 8-inch cut of clean coal.

Section B (sample 16056) was measured at the face of room 4, off east entry 5. The sample represented a 7-foot 2-inch cut of clean coal.

Section C (sample 16057) was measured at the face of room 13, off east entry 3. The sample represented a 7-foot 7-inch cut of clean coal.

Section D (sample 16058) was measured at the face of room 11, off east entry 2. The sample represented a 6-foot 9-inch cut of clean coal.

A composite sample was made by mixing samples 16056 to 16058, inclusive. The results of an ultimate analysis of this sample are shown under laboratory No. 16059.

Notes.—The New Acme mine is opened by a drift. The coal was mined by the room-and-pillar and later by the panel system. At the time of sampling the coal was undercut by electric breast machines and broken down with black powder. About 35 per cent of the coal was shipped as run-of-mine, 70 per cent of the coal going to the screen passed through. The screening equipment consisted of bars 4 by 8 feet with 5-inch openings; shaker screens 8 by 12 feet, the diameter of holes being 1½, 2½, 4, and 6 inches; and revolving screens 24 feet long divided into sections as follows: 8 feet with ½-inch holes, 8 feet with 1-inch holes, 4 feet with 2½-inch holes, and 4 feet with 3½-inch holes. No pickers were employed on the cars. The mine had a storage bin of 500 tons capacity. The lump coal on the cars appeared dull; the lumps were small. The mine had three loading tracks with a capacity for 86 empty cars and 86 loaded cars. A runaround for switching permitted loading while cars were being shifted or loads taken out. As the tipple was rather high, there was more or less breakage in the handling of the coal. There was approximately 1,000 acres to be mined. The daily output averaged about 1,000 tons, with a maximum day's run of 1,420 tons. The estimated life of the mine was 50 years.

SWEETWATER COUNTY.

GUNN. "B" MINE.

Sample.—Subbituminous coal; Rock Springs field; analyses Nos. 11507, 11508, 11509, and 11510 (p. 144).

Mine.—Gunn-Quealy "B," a slope mine in sec. 8, T. 19 N., R. 104 W., at Gunn, 4 miles from Baxter, on a branch line from the Union Pacific Railroad.

Coal bed.—Locally known as No. 11. Cretaceous age, Mesaverde formation. Average thickness, 6 feet 1 inch; dip, 7½° S., 80° W.; cleat S. 70° E. Roof, shale. about 16 feet thick; floor, shaly sandstone; cover, at points where samples were taken, 350 to 360 feet thick.

The bed was measured and sampled at three points in the mine by S. S. Smith on December 22, 1910, as described below:

Section A (sample 11507) was measured at the face of room 15, off entry 5. The sample represented a 6-foot 2-inch cut.

Section B (sample 11508) was measured at the face of room 25, off entry 4. The sample represented a 6-foot 1-inch cut.

Section C (sample 11509) was measured at the face of room 8, off entry 8. The sample represented a 6-foot 2-inch cut.

Notes.—The room-and-pillar system of mining was employed. At the time of sampling the coal was undercut with electric chain cutters. Black powder was used for breaking down the coal and dynamite for brushing the roof. About 30 per cent of the coal was shipped as run-of-mine; the remainder was sized by shaking and revolving screens. No hand picking was done. There were four loading tracks with capacity for 100 cars.

The daily production was 1,000 tons, 80 per cent being obtained from advance work. About 375 acres of unmined coal was tributary to this slope.

SUPERIOR. B MINE.

Sample.—Bituminous coal; Rock Springs field; analyses Nos. 11461, 11462, 11463, and 11464 (p. 144).

Mine.—B, a drift mine in sec. 29, T. 21 N., R. 102 W., 2 miles northeast of Superior, on a branch of the Union Pacific Railroad from Thayer Junction and only a few miles north of the main line.

Coal bed.—No. 1. Cretaceous age, Mesaverde formation. Locally known as No. 7 of the Laramie. Average thickness, 6 feet 6 inches; dip, 4½° NE. The roof is a smooth black shale 15 feet thick with a sandstone cap rock; the floor is a hard smooth shale; the covering at the point of sampling is 400 feet.

The bed was measured and sampled at four points in the mine by S. S. Smith on December 14, 1910, as described below:

Sections of coal bed in the B mine.

Section	A		B		C		D	
Laboratory No.	11461		11462		11463		11464	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	..	..	1	1	1	6	..	..
Rock parting	..	..	0	¼	0	¼	..	..
Coal	7	2	6	3½	5	9½	6	3½
Floor, shale.								
Thickness of bed	7	2	7	4¾	7	3¾	6	3½
Thickness of coal sampled	7	2	7	4¾	7	3¾	6	3½

Section A (sample 11461) was measured at the face of room 27, off the inside dip entry.

Section B (sample 11462) was measured at the face of south entry 2.

Section C (sample 11463) was measured at the face of room 20, off south entry 3.

Section D (sample 11464) was measured at the face of room 11, off north entry 3.

Notes.—The coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut with electric chain cutters; black powder and a permissible explosive was used for breaking down the coal; 75 per cent of the coal produced was from advance workings; daily output 1,200 tons; unmined area tributary to this opening, 250 acres.

SUPERIOR. SUPERIOR C MINE.

Sample.—Subbituminous coal; Rock Springs field; analyses Nos. 11456, 11457 11458, and 11459 (pp. 144, 145).

Mine.—C, a slope mine in sec. 21, T. 21 N., R. 102 W., at Superior, on a branch line of the Union Pacific Railroad from Thayer Junction.

Coal bed.—Unnamed. Cretaceous age, Mesaverde formation, known locally as No. 1 of the Laramie. Average thickness, 8 feet 6 inches; dip 4½° NE. The cleat is well defined and extends east and west. Roof, black shale 4 to 8 feet thick, above which is a heavy capping of sandstone; floor, hard, smooth shale. The cover at points where samples were taken is about 250 feet.

The bed was measured and sampled at four points by S. S. Smith on December 14, 1910, as described below:

Sections of coal bed in the Superior C mine.

Section	A		B		C		D	
Laboratory No.	11456		11457		11458		11459	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	1	10	2	3	..	..	2	3
Rock	[a]0	1½	[a]0	1¾	..	..	[a]0	1½
Coal	6	8	6	3	6	7	6	2
Floor, shale.								
Thickness of bed	8	7½	8	7¾	6	7	8	6½
Thickness of coal sampled	8	6	8	6	6	7	8	5

[a] Not included in sample.

Section A (sample 11456) was measured at the face of room 15, off south entry 6.

Section B (sample 11457) was measured at the face of room 25, off south entry 5.

Section C (sample 11458) was measured at the face of room 1, off north entry 7.

Section D (sample 11459) was measured at the face of room 38, off south entry 4.

Notes.—The mine is opened by a slope in the coal bed and is worked by the room-and-pillar system. At the time of sampling 90 per cent of the coal produced was from advance work; black powder and a permissible explosive were used for breaking the coal after undercutting by electric machines. Daily production of mine, 1,300 to 1,400 tons; unmined area tributary to this opening, 1,200 acres.

UINTA COUNTY.

Elkol. Elkol Mine.

Sample.—Bituminous coal; Kemmerer field; analyses Nos. 11730 and 11731 (p. 145).

Mine.—Elkol, a slope mine in sec. 11, T. 20 N., R. 117 W., near Elkol, 8 miles southwest of Diamondville on the Oregon Short Line Railroad.

Coal bed.—Locally known as No. 1. Cretaceous age, Frontier formation. The coal bed is 51 feet thick and at the points where the samples were taken is 1,600 feet below the surface. The coal bed was sampled at 2 points in the mine by S. S. Smith on February 9, 1911, as described below:

Sections of coal bed in Elkol mine.

Section	A		B	
Laboratory No.	11730		11731	
Roof, not stated.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	[a]27	6	[a]27	6
Coal, soft and black	8	6	8	6
Coal	[a]15	0	[a]15	0
Floor, not stated.				
Thickness of bed	51	0	51	0
Thickness of coal sampled	8	6	8	6

[a] Not included in sample.

Section A (sample 11730) was measured at the face of north entry 3, 1,900 feet from the slope mouth.

Section B (sample 11731) was measured at the face of room 1, off north entry 3.

Notes.—The State mine inspector's report for the fiscal year ended September 30, 1910, gives the total production for that year as 50,000 tons, which was shipped to points in Utah, Idaho, Oregon, Washington, and California.

Frontier. Kemmerer No. 1 Mine.

Sample.—Bituminous coal; Kemmerer field; analyses Nos. 11565, 11566, 11567, and 11568 (p. 145).

Mine.—No. 1, a slope mine in sec. 12, T. 21 N., R. 116 W., at Frontier, on a branch of the Oregon Short Line Railroad.

Coal bed.—Cretaceous age, Frontier formation. Locally known as No. 1 of the Laramie. Average thickness, 7 feet; dip, 13° west; well-defined cleat. Roof, draw slate, 3 feet 6 inches thick, which stands fairly well, overlain by shaly sandstone; floor, hard, smooth fire clay. Cover at points where samples were taken varies from 175 to 400 feet.

The bed was measured and sampled at four points in the mine by S. S. Smith on January 11, 1911, as described below:

Sections of coal bed in the Kemmerer No. 1 mine.

Section	A		B		C		D	
Laboratory No.	11565		11566		11567		11568	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal (hard)	3	7	4	9	1	6	1	6
Soft rock parting	[a]0	½	[a]0	4	[a]0	6	[a]0	10
Coal (soft)	4	9	3	4	3	10	3	8
Floor, fire clay.								
Thickness of bed	8	4½	8	5	5	10	6	0
Thickness of coal sampled	8	4	8	1	5	4	5	2

[a] Not included in sample.

Section A (sample 11565) was measured at the face of room 16, off south entry 13, and 400 feet below the surface.

Section B (sample 11566) was measured on the pillar of room 18, off north entry 10, and 240 feet below the surface.

Section C (sample 11567) was measured at the face of room 3, off north entry 7, and 175 feet below the surface.

Section D (sample 11568) was measured on the pillar of room 62, off south entry 7, and 200 feet below the surface.

Notes.—The mine is worked by the room-and-pillar system. At the time of sampling the coal was shot from the solid with FFF black powder. The coal was shipped as run-of-mine; the lumps were large and bright, but the slack was dull. Pickers sorted out inferior coal and shale as the coal was loaded on the car. There were 5 loading tracks with capacity for 150 cars. The daily production was 600 tons.

For analyses and descriptions of other samples of coal from this mine see Bull. 22, p. 1150.

KEMMERER. PROSPECT.

Sample.—Subbituminous coal; Kemmerer field, analysis No. 11740 (p. 145).

Mine.—A prospect in sec. 33, T. 22 N., R. 116 W., 2½ miles north of the Oregon Short Line Railroad and 1½ miles west of Kemmerer.

Coal bed.—Cretaceous age, Frontier formation. Thickness, 16 feet; roof, sandstone; floor, fire clay.

The bed was sampled by S. S. Smith on February 12, 1911, at the face of the first entry, 200 feet from the mouth of the slope. The vertical depth at which the sample was taken was 150 feet.

SUSIE. KEMMERER NO. 4 MINE.

Sample.—Bituminous noncoking coal; analyses Nos. 13517, 13518, and 13519 (p. 145).

Mine.—Kemmerer No. 4, a slope mine at Susie, 4 miles north of Kemmerer, on a spur of the Oregon Short Line Railroad, secs. 25 and 26, T. 22 N., R. 116 W.

Coal bed.—Kemmerer No. 1. Cretaceous age, Frontier formation. Average thickness, 3 feet 7 inches to 5 feet 6 inches; dip 19° W.; no faults but a few rolls and horsebacks; cleat runs north and south. Roof, shale; in places there is as much as 3 feet of "draw slate," which comes down with the coal. The floor consists of a hard rough shale. Particles of the roof and floor did not get mixed with the coal in loading. The thickness of the cover at the points where the samples were taken varies from 700 to 750 feet.

The coal bed was measured and sampled at two points in the mine by J. C. Roberts on January 23, 1912, as described below:

Sections of coal bed in Kemmerer No. 4 mine.

Section	A		B	
Laboratory No.	13517		13518	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*
Coal	3	6	4	3
Clay parting	0	2	..	..
Coal	1	6	..	..
Floor, shale.				
Thickness of bed	5	2	4	3
Thickness of sampled	5	2	4	3

Section A (sample 13517) was measured 1,000 feet from mouth of slope.

Section B (sample 13518) was measured at the face of the second north entry, 1,300 feet from mouth of slope.

A composite sample was made by mixing samples 13517 and 13518. The results of an ultimate analysis of this sample are shown under laboratory No. 13519.

Notes.—The No. 4 mine was opened by a slope and the coal was mined by the room-and-pillar system. The coal was shot off the solid with black powder. Dynamite was used in brushing the floor and roof. The screening equipment consisted of shaking screens 32 feet long and 6 feet wide—16 feet with 3-inch openings and 16 feet with ¾-inch openings. No pickers were employed on the cars. There were five loading tracks with a capacity of 30 empty cars and 20 loaded cars. The average daily output was 500 tons a day with a maximum day's run of 700 tons; all of the coal was shipped as run-of-mine. About 75 per cent of the coal was taken from advance workings.

WESTON COUNTY.

CAMBRIA. ANTELOPE NO. 3 AND NO. 4 MINES.

Sample.—Subbituminous to cannel coal; Black Hills region (Wyoming No. 2) analyses Nos. 16412, 16413, 16414, 16415, 16428, 16429, 16430, and 16431 (p. 146).

Mine.—Antelope No. 3 and No. 4, drift mines at Cambria, in secs. 19 and 20, T. 46 N., R. 61 W., at end of the spur of the Chicago, Burlington & Quincy Railroad, 6½ miles from Newcastle.

Coal bed.—Not named, probably a local bed. Cretaceous age, Lakota formation. Average thickness, 5 feet, varying from 2 feet 6 inches to 8 feet. Many mud and sand pockets occur in parts of the mine. Sandstone, shale, and bony coal partings appear in the coal at varying intervals. The coal itself varies greatly in character from subbituminous to cannel coal. The coal bed is uneven; one room may be going to the dip and a parallel room going to the rise. Roof, a black sandy shale over which is 1 to 2 feet of granular sandstone which gives considerable trouble if not closely watched. Floor is rough and uneven; small metallic concretions and large hard nodules called "nigger heads" are common. It is for the most part hard black shale and sandstone. Particles of the roof and bottom did not mix with the coal in loading. The thickness of the cover at the points where the samples were taken varies from 25 feet to 225 feet.

The coal bed was measured and sampled at six points in the mine by O. U. Bradley on February 11 and 12, 1913, as described below:

Sections of coal bed in the Antelope No. 3 and No. 4 mines.

Section	A		B		C		D		E		F	
Laboratory No.	16412		16413		16414		16428		16429		16430	
Roof, shale.	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	..	..	3	2	2	3	..	..	1	0	2	1
Rock or splint	..	..	[a]0	8	[a]1	9	..	..	[a]0	6	[a]0	6
Coal	0	8	0	11	1	4	..	..	1	0	..	..
Rock	[a]1	0	[a]0	2	[a]1	0	..	..	[a]0	3	..	..
Coal	2	3	1	2	2	7	[b]3	9	4	6	4	10
Floor, black shale and sandstone.												
Thickness of bed	3	11	6	1	8	11	3	9	7	3	7	5
Thickness of coal sampled	2	11	5	3	6	2	3	9	6	6	6	11

[a] Not included in sample.
[b] Contains two streaks of bony coal ½ to ¾ inch thick, which is loaded with the coal.

Section A (sample 16412) was measured at the face of east entry 1, No. 4 mine.

Section B (sample 16413) was measured at the face of north entry 1, off east entry 1, No. 4 mine.

Section C (sample 16414) was measured at the face of room 29, off east entry 3, No. 4 mine.

A composite sample was made by mixing samples 16412, 16413, and 16414. The results of an ultimate analysis of this sample are given under laboratory No. 16415.

Section D (sample 16428) was measured at the face of room 35, off east entry 5, No. 3 mine.

Section E (sample 16429) was measured at the face of west entry 8, No. 3 mine.

Section F (sample 16430) was measured at the face of west entry 7, No. 3 mine.

A composite sample was made by mixing samples 16428, 16429, and 16430. The results of an ultimate analysis of the sample are given under laboratory No. 16431.

Notes.—The coal is mined by the room-and-pillar system. At the time of sampling the coal was undercut by compressed-air punching machines and broken down with black blasting powder. Dynamite was used for brushing the floor and roof. The machine cuttings were loaded with the coal. The entire output of the mines was run through a rock crusher to facilitate picking. It was then sized and resized and loaded into cars. The Chicago, Burlington & Quincy Railroad bought the entire output for steaming purposes. The coal burns well, especially under forced draft, and is particularly suited to railroad work.

Moorcroft. Local Mine.

Sample.—Subbituminous coal; Upper Belle Fourche River field; analysis No. 12446 (p. 146).

Mine.—Local drift mine, 12 miles south of Moorcroft and of the Chicago, Burlington & Quincy Railroad.

Coal bed.—Not named, a local bed.

The bed was measured and sampled by A. W. Stickney on July 17, 1911, as described below:

Section of coal bed in local mine, about 12 miles south of Moorcroft.

Laboratory No.	12446	
Roof, sandy shale.	*Ft.*	*in.*
Bone	[a]0	1
Coal	2	11
Floor, carbonaceous shale.		
Thickness of bed	3	0
Thickness of coal sampled	2	11

[a] Not included in sample.

The sample was taken from the face of the entry, 100 feet from the entrance.

Moorcroft. Prospect.

Sample.—Subbituminous coal; Upper Belle Fourche River field; analysis No. 12392 (p. 146).

Location.—Prospect opened by sampler about 12 miles southwest of Moorcroft and of the Burlington Railroad, in the SE. ¼ sec. 29, T. 48 N., R. 68 W.

Coal bed.—Local lense in Lance formation. Tertiary or Cretaceous age. Thickness, 2 feet 4 inches; roof, clay; floor, carbonaceous shale.

The bed was measured and sampled by A. W. Stickney on June 27, 1911. The sample represented a 2-foot 4-inch cut of coal, the thickness of the bed.

BIBLIOGRAPHY.

Under the description of each sample in this report reference has been made to the publication of the United States Geological Survey containing a description of the geologic relations of the coal bed or the composition of the coal.

A bibliographical list of the United States Geological Survey publications dealing with coal is given in "Mineral Resources of the United States, 1910" (U. S. Geol. Survey, 1911), pages 226–242. This list is also published as a separate by the United States Geological Survey.

The references given below are chiefly the publications of State surveys, and refer to papers of a general nature rather than to descriptions of separate localities. The list is incomplete, but it is believed to contain the more important references, other than those in reports of the Geological Survey, to the composition and geologic relations of the various coals in this country.

ALABAMA.

Gibson, A. M. Report on the Coal Measures of Blount Mountain, with map and sections. Ala. Geol. Surv., 1893, pp. 7–80. Describes the topography and geologic structure of the region and the stratigraphy of the lower and upper coal measures, with a detailed description of the coal seams. Gives chemical analyses of some of the coals.

McCalley, Henry. Report on the coal measures of the plateau region of Alabama. Ala. Geol. Surv., 1891, 238 pp.

——— Report on the Tennessee Valley region. Ala. Geol. Surv. Rept., pt. 1, 1896, 436 pp. Describes the general features of the stratigraphy, and the occurrence of coal, etc. Gives local geologic details by counties.

——— Report on the Warrior coal basin. Ala. Geol. Surv., 1900, 327 pp. Gives numerous sections of coal beds.

Squire, Joseph. Report on the Cahaba coal field. Ala. Geol. Surv., 1890, 187 pp.

ARKANSAS.

Steel, A. A. Coal mining in Arkansas. Geol. Surv. of Ark., vol. 1, 1910, 632 pp.; vol. 2, 1910, 383 pp.

Winslow, Arthur. The geology of the coal regions. Ann. Rept. Geol. Surv. of Ark. for 1888, vol. 3, 1888, 122 pp. Gives geologic sections, also analyses of coals.

COLORADO.

Colorado State Bureau of Mines. Report of the State Bureau of Mines for the years 1905–6. 1907. 127 pp.

Headden, W. P. A study of some Colorado coals—a comparison of some coals from Boulder, Routt, and Delta Counties. Colo. Sci. Soc. Proc., vol. 8, May, 1907, pp. 281–300.

——— An examination of some coals from Routt County, Colo. Colo. Sci. Soc. Proc., vol. 8, March, 1907, pp. 257–280.

Parsons, H. F., and Liddell, C. A. The coal and mineral resources of Routt County. Colorado School of Mines Bull., vol. 1, no. 4, 1903, pp. 47–59.

GEORGIA.

McCallie, S. W. A preliminary report on the coal deposits of Georgia. Geol. Surv. Ga. Bull. 12, 1904, 121 pp.

——— A preliminary report on the mineral resources of Georgia. Geol. Surv. Ga. Bull. 23, 1910, pp. 67–75.

ILLINOIS.

Bain, H. F., and others. Studies of Illinois coals. Am. Inst. Min. Eng. Bull. 24, 1908, pp. 1099–1170.

——— Studies of Illinois coal. Ill. State Geol. Surv. Bull. 14, 1909, pp. 183–253.

Bement, A. Distribution of the coal beds of the State [of Illinois]. Ill. State Geol. Surv. Bull. 3, 1906, pp. 19–25. Discusses the occurrence and mining of the workable seams of Illinois.

——— The Illinois coal field. Ill. State Geol. Surv. Bull. 16, 1910, pp. 182–202.

Cady, G. H. The geology and coal resources of the West Frankfort quadrangle. Ill. State Geol. Surv. Bull. 16, 1910, pp. 244–265.

De Wolf, F. W. Coal investigations in Saline and Williamson Counties, Ill. Ill. State Geol. Surv. Bull. 8, 1908, pp. 230–245. Describes the stratigraphy and structure of the field, and the occurrence and character of the coals.

——— Coal investigations in the Saline-Gallatin field, Illinois, and the adjoining area. Ill. State Geol. Surv. Bull. 8, 1908, pp. 211–229.

——— The coal resources of Illinois. Am. Inst. Min. Eng. Bull. 24, November, 1908, pp. 1103–1112.

——— The coal resources of Illinois. Ill. State Geol. Surv. Bull. 14, 1909, pp. 189–196.

De Wolf, F. W., and others. Studies of Illinois coal. Ill. State Geol. Surv. Bull. 16, 1910, pp. 177–301.

Lindgren, J. M. The sampling and analysis of Illinois coals. Ill. State Geol. Surv. Bull. 14, 1909, pp. 196–203. Gives analyses of coals from various parts of the State.

Parr, S. W. Chemical analyses of certain coals. Ill. State Geol. Surv. Bull. 4, 1907, pp. 188–197.

——— Composition and character of Illinois coals. Ill. State Geol. Surv. Bull. 3, 1906, pp. 27–78.

——— The chemical composition of Illinois coal. Ill. State Geol. Surv. Bull. 16. 1910, pp. 203–243.

Savage, T. E. The geology and coal resources of the Herrin, Ill., quadrangle. Ill. State Geol. Surv. Bull. 16, 1910, pp. 266–285.

Shaw, E. W. The geology and coal resources of the Murphysboro quadrangle, Illinois, Ill. State Geol. Surv. Bull. 16, 1910, pp. 286–294.

Udden, J. A. Coal deposits and possible oil field near Duquoin, Ill. Ill. State Geol. Surv. Bull. 14, 1909, pp. 254–262.

Udden, J. A., and De Wolf, F. W. Notes on the Belleville-Breese area. Ill. State Geol. Surv. Bull. 8, 1908, pp. 313–334.

INDIANA.

Ashley, G. H. Supplementary report [to report of 1898] on the coal deposits of Indiana. Ind. Dept. Geol. and Nat. Res., 33d Ann. Rept., 1909, pp. 13–150.

——— The coal deposits of Indiana. Ind. Dept. Geol. and Nat. Res., 23d Ann. Rept., 1899, pp. 1–1428. Describes general geologic occurrence and distribution of coal, the general geology of the coal measures of Indiana, and the detailed geology in various counties. Presents analyses of certain coals.

Noyes, W. A. Composition of Indiana coals. Ind. Dept. of Geol. and Nat. Hist., 21st Ann. Rept., 1897, pp. 97–107. Describes the methods of analyses and in tabular form shows the chemical composition of coal from various mines.

IOWA.

Arey, M. F. Geology of Davis County. Iowa Geol. Surv., vol. 20, 1910, pp. 487–524.

——— Geology of Wayne County. Iowa Geol. Surv., vol. 20, 1910, pp. 199–236.

Beyer, S. W. Coal statistics [Iowa]. Iowa Geol. Surv., vol. 19, 1909, pp. 591–597.

——— Mineral production in Iowa in 1905. Iowa Geol. Surv., vol. 16, 1906, pp. 17–36.

Beyer, S. W., and Young, L. E. Geology of Monroe County [Iowa]. Iowa Geol. Surv., vol. 13, 1903, pp. 355–422. Describes the character and occurrence of coal seams and the coal-mining operations in the county, and gives analyses of certain coals.

Hinds, Henry. The coal deposits of Iowa. Iowa Geol. Surv., vol. 19, 1909, pp. 21–396.

Keyes, C. R. Coal deposits of Iowa. Iowa Geol. Surv., vol. 2, 1894, 536 pp.

——— Stages of the Des Moines or chief coal-bearing series of Kansas and southwest Missouri and their equivalents in Iowa. Iowa Acad. Sci. Proc., vol. 4, 1897, pp. 22–25.

Lees, J. H. Bibliography of Iowa coals. Iowa Geol. Surv., vol. 19, 1909. pp. 659–697.

——— History of coal mining in Iowa. Iowa Geol. Surv., vol. 19, 1909, pp. 523–588.

Lees, J. H., and Hixon, A. W. Analyses of Iowa coals. Iowa Geol. Surv., vol. 19, 1909, pp. 476–519.

Macbride, T. H. Geology of Hamilton and Wright Counties. Iowa Geol. Surv., vol. 20, 1910, pp. 97–149.

Savage, T. E. Report on tests of Iowa coals made at the Government coal-testing plant at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. Iowa Geol. Surv. Bull. 2, 1905, pp. 22–38.

Wilder, F. A. Fuel values of Iowa coals. Iowa Geol. Surv., vol. 19, 1909, pp. 397–475.

KANSAS.

Crane, W. R. Geography and detailed stratigraphy of the Kansas Coal Measures; description of mines, mining methods, and mining machinery; chemical and physical properties of Kansas coals; output and commerce; mining directory and mining laws. Kans. Univ. Geol. Surv., vol. 3, 1898, pp. 108–336.

Haworth, Erasmus. The coal fields of Kansas. Kans. Univ. Quart., vol. 3, 1895, pp. 297–309.

——— The stratigraphy of the Kansas Coal Measures. Kans. Univ. Quart., vol. 3, 1895, pp. 271–290.

Langworthy, A. E. The Atchison [Kansas] diamond-drill prospect hole. Kans. Acad. Sci. Trans., vol. 17, 1901, pp. 45–52.

KENTUCKY.

Crandall, A. R. Coals of the Licking Valley region. Ky. Geol. Surv. Bull. 10, 1910, 90 pp.

——— The coals of the Big Sandy Valley south of Louisa and between Tug Fork and the headwaters of the north fork of the Kentucky River. Ky. Geol. Surv. Bull. 4, 1905, 141 pp. Describes the general geology and topography of the area, the occurrence, character, thickness, and relations of the coal seams, giving numerous sections, and the character and composition of the coals.

Fohs, F. J. Coals of the region drained by the Quicksand Creeks in Breathitt, Floyd, and Knott Counties. Ky. Geol. Surv. Bull. 18, 1912, 79 pp. Discusses geology of the coal beds and presents analyses of coals.

Glenn, L. C. A geological reconnoissance of the Tradewater River region, with special reference to the coal beds. Ky. Geol. Surv. Bull. 17, 1912, 75 pp.

Hodge, J. M. Report on the coals of the three forks of the Kentucky River. Ky. Geol. Surv. Bull. 11, 1910, 280 pp. Presents analyses and discusses the geology.

——— Summary of report on the region drained by the three forks of the Kentucky River. Ky. Geol. Surv. Rept. of Progress for 1906 and 1907, 1908, pp. 36–45. Includes an account of the distribution and character of the coal beds in this area.

——— The Big Stone Gap coal field. Trans. Am. Inst. Min. Eng., vol. 21, 1893, pp. 922–938, 1005–1006. Describes the geology of the region, illustrated by sections of Little and Big Black Mountain and the geologic position of the different coal beds with a statement of the character of the coal found in each bed.

Macfarlane, Graham. The eastern coal region of Kentucky. Trans. Am. Inst. Min. Eng., vol. 25, 1896, pp. 518–532. Gives a section showing the vertical distribution of the coal seams and describes the general features of the coal measures of the region.

Miller, A. M. Abstract of report on the lower (or "conglomerate") measures along the western border of the eastern coal field. Ky. Geol. Surv. Rept. of Progress for 1906 and 1907, 1908, pp. 27–35.

——— Coals of the lower measures along the western border of the eastern coal field. Ky. Geol. Surv. Bull. 12, 1910, 83 pp.

Norwood, C. J. Annual reports of the inspector of mines of the State of Kentucky for 1901 and 1902. 1903. 140 pp. Coals of the different districts described.

Peter, Robert. Chemical report of the coals, clays, mineral waters, etc., of Kentucky. Ky. Geol. Surv. Bull. 3, 1905, 77 pp.

MARYLAND.

Clark, W. B., and others. Report on the coals of Maryland. Md. Geol. Surv. special publication, vol. 5, pt. 4, pp. 221–651.

Clark, W. B., and Mathews, E. B. Maryland mineral industries, 1896–1907. Md. Geol. Surv., vol. 8, 1909, pp. 97–223.

MICHIGAN.

Cooper, W. F. Geological report on Bay County [Michigan]. Mich. State Board of Geol. Surv. Ann. Rept., 1905, 1906, pp. 135–426.

Lane, A. C. Coal of Michigan: its mode of occurrence and quality. Mich. Geol. Surv., vol. 8, pt. 2, 1902, pp. 1–232.

——— Fifth annual report of the State geologist [Michigan]. Mich. Geol. Surv. Ann. Rept. for 1903, 1905, 342 pp.

——— Sixth annual report of the State geologist [of Michigan] for 1904. Mich. Geol. Surv. Ann. Rept. for 1904, 1905, pp. 113–168.

MISSISSIPPI.

Brown, C. S. Lignite of Mississippi. Miss. Geol. Surv. Bull. 3, 1907, 71 pp.

MISSOURI.

Barbour, E. H. Report on the Honey Creek coal mine. Mo. Geol. Surv., vol. 2, 1907, pp. 349–364.

Bush, B. F. The coal fields of Missouri. Am. Inst. Min. Eng. Bull. 1, 1905, pp. 165–179; Trans., vol. 35, 1905, pp. 903–917.

Gordon, C. H. A report of the Bevier sheet, including portions of Macon, Randolph, and Chariton Counties [Missouri]. Mo. Geol. Surv., vol. 9, 1896, 75 pp. Describes the physiographic character of the region and the economic geology of the coal beds.

Hinds, Henry. The coal deposits of Missouri. Mo. Bureau Geol. and Mines, vol. 11, ser. 2. 1903. 503 pp. Gives a detailed comprehensive account of the geologic relations of the coal beds and the character and composition of the coal.

White, David. Age of the lower coals of Henry County, Missouri. Geol. Soc. Am. Bull., vol. 8, 1897, 287–304.

Winslow, Arthur. A preliminary report on the coal deposits of Missouri. Mo. Geol. Surv., 1891, pp. 19–226. Describes the topographic and geologic features of the coal-measures formation, the process of its deposition, the distribution and character of the contained coal beds, and the conditions of the coal industry. Gives a description of the coal seams now worked in each county.

——— A report on the Higginsville sheet, Lafayette County [Missouri]. Mo. Geol. Surv., vol. 9, 1896, 99 pp. Describes the physiography of the region, the distribution and character of the Carboniferous and Quaternary formations, and the occurrence and character of the coal seams.

MONTANA.

Rowe, J. P. Montana coal and lignite deposits. Mont. Univ. Bull. 37 (Geol. Ser. 2), 1906, 82 pp.

Stebinger, Eugene. The coal fields of Montana. Am. Inst. Min. Eng. Bull. 81, pp. 2329–2359, September, 1913.

NEW MEXICO.

Sheridan, J. E. Report of the mine inspector for the Territory of New Mexico to the Secretary of the Interior for the year ended June 30, 1906. 1906. 87 pp. Includes notes on the occurrence and character of coal seams and chemical analyses of coals.

Stevenson, J. J. The Cerillos coal fields near Santa Fe, New Mexico. N. Y. Acad. Sci., Trans., vol. 15, 1896, pp. 105–122. Describes the character of the Cretaceous deposits and the occurrence and chemical composition of the coals.

NEBRASKA.

Barbour, E. H. Report of the State geologist. Nebr. Geol. Surv., vol. 1, 1903, 258 pp. Includes analyses of certain coals.

Pepperburg, R. V. Coal in Nebraska. Nebr. Geol. Surv., vol. 3, pt. 10, 1910, pp. 275–307.

NORTH DAKOTA.

Leonard, A. G., and others. Geology of southwestern North Dakota, with special reference to the coal. N. Dak Geol. Surv., 5th Bienn. Rept., 1908, pp. 27–114.

OKLAHOMA.

Gould, C. N., and others. Brief chapters on Oklahoma's minerals. Okla. Geol. Surv. Bull. 6, 1910, pp. 33–95.

OHIO.

Bownocker, J. A. Coals of the Monongahela formation or upper productive coal measures. Ohio Geol. Surv., 4th ser., Bull. 9, 1908, pp. 9–170.

Lord, N. W., and Somermeier, E. E. Chemical analyses and calorific tests of the Clarion, Lower Kittanning, Middle Kittanning, and Upper Freeport coals. Ohio Geol. Surv., 4th ser., Bull. 9, 1908, pp. 170–339.

Orton, Edward. The coal fields of Ohio. Ohio Geol. Surv., vol. 7, 1893, pp. 253–290. Discusses the origin of coal and describes the various coal seams of the Carboniferous strata in Ohio.

PENNSYLVANIA.

Ashburner, C. A. First report of progress in the anthracite district, southern field, Panther Creek basin. 2d Geol. Surv. Pa. Rept. AA, 1883, 407 pp.

Boileau, J. W. Coal fields of southwestern Pennsylvania, Washington, and Greene Counties. 1907. 90 pp.

Chance, H. M. A revision of the bituminous coal measures of Clearfield County. 2d Geol. Surv. Pa. Rept. H7, 1884, pp. XI–XV.

Hill, F. A. Geology and mining in the northern coal field of Pennsylvania. Trans. Am. Inst. Min. Eng., vol. 15, 1887, pp. 699–707.

——— Report on the anthracite region. Geol. Surv. Pa. Rept. for 1886, pt. 3, 1887, pp. 919–1329.

Lesley, J. P. Manual of coal and its topography illustrated by original drawings, chiefly of facts in the geology of the Appalachian region of the United States of North America. 1856. 224 pp.

——— Note on classification of coals. 2d Geol. Surv. Pa. Rept. MM, 2d Rept. of progress in the laboratory of the survey at Harrisburg, 1879, pp. 144–157.

——— On the Broad Top coal basin in central Pennsylvania. Am. Assoc. Proc., vol. 10, pt. 2, 1857, pp. 78–81.

——— The coal beds and fire clays of the Wellersburg basin, in Somerset County, Geol. Surv. Pa. Ann. Rept. for 1885, 1886, pp. 227–239.

Lesquereaux, Leo. On the character and distribution of Paleozoic plants. Geol. Surv. Pa. Ann. Rept. for 1886, 1887, pp. 457–522.

——— On the vegetable origin of coal. Geol. Surv. Pa. Ann. Rept. for 1885, 1886, pp. 95–121.

Platt, Franklin, and Platt, W. G. Report of progress in the Cambria and Somerset district of the bituminous coal fields of western Pennsylvania, part 1, Cambria 2d Geol. Surv. Pa. Rept. HH, 1877, 194 pp.

——— Report of progress in the Cambria and Somerset district of the bituminous coal fields of western Pennsylvania. 2d Geol. Surv. Pa. Rept. HHH, 1877, 348 pp.

Rogers, H. D. The geology of Pennsylvania. Vol. 1, 586 pp.; vol. 2, 1045 pp. 1858.

Stevenson, J. J. Report of progress in the Greene and Washington district of the bituminous coal fields of western Pennsylvania. 2d Geol. Surv. Pa. Rept. K for 1875, 1876, 419 pp.

White, I. C. Geology of Lawrence County. 2d Geol. Surv. Pa. Rept. QQ, 1879, pp. 1–213.

——— Geology of Susquehanna River region in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Montour, and Northumberland. 2d Geol. Surv. Pa. Rept. G7, 1883, 464 pp.

——— Report of the progress of the second geological survey of Pennsylvania in parts of Beaver, Allegheny, and Butler Counties lying north of the Ohio River. 2d Geol. Surv. Pa. Rept. Q for 1875, 1878, pp. 1–273.

——— Special report on the correlation of the coal measures in western Pennsylvania and eastern Ohio. 2d Geol. Surv. Pa. Rept. QQ, 1879, pp. 215–303.

——— Stratigraphy of the bituminous coal fields of Pennsylvania, Ohio, and West Virginia. U. S. Geol. Surv. Bull. 65, 1891, 212 pp.

——— The geology of Mercer County. 2d Geol. Surv. Pa. Rept. QQQ, 1880, 233 pp.

RHODE ISLAND.

Brown, C. W. Preliminary report of the natural resources survey of Rhode Island. R. I. Bureau Industrial Statistics, Ann. Rept. for 1909, pt. 3, 1910, pp. 59–128. Includes an account of the coal deposits.

TENNESSEE.

Ashley, G. H. The Tennessee coal field. Resources of Tennessee, vol. 1, October, 1911, pp. 188–202.

Glenn, L. C. The general features of the Tennessee coal field north of the Tennessee Central Railroad. Tennessee State Geol. Survey, Resources of Tennessee, vol. 3, No. 1, January, 1913, pp. 4–25. (Also published in Bulletin 2–B.)

Nelson, W. A. The Tennessee coal field south of the Tennessee Central Railroad. Tennessee State Geol. Survey, Resources of Tennessee, vol. 3, No. 1, January, 1913, pp. 26–49. (Also published in Bulletin 2–B.)

Phalen, W. C. Preliminary report of the coal resources of the Pikeville special quadrangle of eastern Tennessee. Resources of Tennessee, vol. 1, September, 1911, pp. 117–162.

TEXAS.

Ashburner, C. A. Brazos coal field, Texas. Trans. Am. Inst. Min. Eng., vol. 9, 1881, pp. 495–506.

Drake, N. F. Report on the Colorado coal field of Texas. Tex. Geol. Surv. 4th Ann. Rept., 1893, pp. 357–446.

Dumble, E. T. Report on the brown coal and lignite of Texas. Tex. Geol. Surv. 1892, pp. 17–243. Describes the origin, formation, and characters of brown coal, the geology of the Texas deposits, and the occurrence and composition of the Tertiary brown coals in the different States, and compares them with European brown coals.

Phillips, W. B. Coal, lignite, and asphalt rocks [Texas]. Tex. Univ. Mineral Surv. Bull. 3, 1902, pp. 137.

——— The coal, lignite, and asphalt rocks of Texas. Western Soc. Engrs. Jour., vol. 9, 1904, pp. 571–592.

Phillips, W. B., and Worrell, S. H. The composition of Texas coals and lignites. Tex. Univ. Bull., Sci. Ser. No. 19, 1911, pp. 5–57.

Simonds, F. W. The minerals and mineral localities of Texas. Tex. Univ. Min. Surv. Bull. 5, 1902, pp. 3–95.

Udden, J. A. A sketch of the geology of the Chisos country, Brewster County, Texas. Univ. of Texas Bull. 93, Apr. 15, 1907, 101 pp.

UTAH.

Harrington, D. Coal mining at Sunnyside, Utah. Colo. Sch. Mines Bull., vol. 1, 1901, pp. 227–235. Describes the general geology, the occurrence of the coal in the Laramie group, and the mining operations.

VIRGINIA.

Bache, Franklin. Coal sections developed by recent operations in Wise County, Virginia. Trans. Am. Inst. Min. Eng., vol. 24, 1895, pp. 70–80. Describes the coal developments and gives sections from various parts of the coal area of the country.

Boyd, C. R. Correlation in the coal rocks west of Pocahontas, Flat Top, Virginia. Trans. Am. Inst. Min. Eng., vol. 24, 1895, pp. 254–257. Remarks on the occurrence of a conglomerate overlying the coal in this region and its bearing on the correlation of the coals.

Hodge, J. M. The Big Stone Gap coal field. Trans. Am. Inst. Min. Eng., vol. 21, pp. 922–938 and 1005–1006.

Lesley, J. P. The geological structure of Tazewell, Russell, and Wise Counties in Virginia. Am. Phil. Soc. Proc., vol. 12, 1873, pp. 489–513.

Watson, T. L. Mineral resources of Virginia. Va. Jamestown Exposition Commission, Lynchburg, 1907, 618 pp. Includes analyses of coals.

WASHINGTON.

EVANS, G. W. The coal fields of King County. Wash. Geol. Surv. Bull. 3, 1912, 247 pp.

LANDES, HENRY. The coal deposits of Washington. Wash. Geol. Surv. Ann. Rept. for 1901, vol. 1, 1902, pp. 257–281.

LANDES, HENRY, and RUDDY, C. A. Coal deposits of Washington. Wash. Geol. Surv. Ann. Rept. for 1902, vol. 2, 1903, pp. 165–277. Describes character, geographic distribution, and geologic relations of the Washington coal beds, the occurrence, thickness, and value of the coal seams, and the constitution and value of the coals.

WEST VIRGINIA.

GRIMSLEY, G. P. Report on the geology of the Panhandle counties of West Virginia. W. Va. County Repts. and Maps: Ohio, Brooke, and Hancock Counties, 1907, 378 pp.

GRISWOLD, W. T. The coals of the Steubenville quadrangle in West Virginia. W. Va. Geol. Surv. County Repts. and Maps: Ohio, Brooke, and Hancock Counties, 1907, pp. 224–237.

HENNEN, R. V. Marshall, Wetzel, and Tyler Counties [W. Va.]. W. Va. Geol. Surv. County Repts., 1909, 654 pp. Describes the area mentioned and the mineral resources, including coal.

——— Wirt, Roane, and Calhoun Counties. W. Va. Geol. Surv., 1911, 573 pp.

HENNEN, R. V., and REGER, D. B. [Report on the history and physiography, geology, and mineral resources of] Marion, Monongalia, and Taylor Counties. W. Va. Geol. Surv., 1913, 844 pp.

KREBS, C. E., and TEETS, D. D., Jr. Cabell, Wayne, and Lincoln Counties]W. Va.]. W. Va. Geol. Surv., County Repts., 1913, 483 pp.

RAMSAY, G. S. The northeastern bituminous coal measures of the Appalachian System. Trans. Am. Inst. Min. Eng., vol., 25, 1896, pp. 76–83.

ROBINSON, NEIL. The Kanawha and New River coal fields of West Virginia, U. S. A., 1904, 23 pp. Includes notes on the occurrence, geologic relations, composition, fuel values, and production of coal.

WEEKS, J. D. The Elk Garden and Upper Potomac coal fields of West Virginia. Trans. Am. Inst. Min. Eng., vol. 24, 1895, pp. 351–364. Gives a general description of the region and tables of chemical analyses of the coal and of coal production.

WHITE, I. C. Levels. Coal analyses. W. Va. Geol. Surv. Bull. 2, 1910, 385 pp.

——— Shortage of coal in the northern Appalachian coal field. Geol. Soc. of America Bull., vol. 20, 1909, pp. 333–340. Discusses the distribution of workable beds, the method of deposition of the coal, and the duration of the field under present methods of mining and use.

——— Supplementary coal report. W. Va. Geol. Surv., vol. 2 (A), 1908, 720 pp. A detailed account of the distribution, geologic relations, and economic value of the coal beds of West Virginia.

——— The Appalachian coal field [West Virginia]. W. Va. Geol. Surv., vol. 2, 1903, pp. 81–716. Gives a detailed account of the Carboniferous system in West Virginia, including geologic sections, the extent, character, and geologic position of the various formations, and the character, occurrence, constitution, and fuel value of the coals.

WYOMING.

KNIGHT, W. C. Coal fields of southern Uinta County, Wyo. Abstract: Geol. Soc. Am. Bull., vol. 13, 1903, pp. 542–544. Describes briefly the Cretaceous strata of the region and gives chemical analyses of the coals.

TRUMBULL, L. W. A preliminary report upon the coal resources of Wyoming. Wyo. Univ. School of Mines Bull. 7, 1905, 19 pp.

PUBLICATIONS ON FUEL TECHNOLOGY.

Limited editions of the following publications of the Bureau of Mines are temporarily available for free distribution. Requests for all publications can not be granted, and applicants should limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines, Washington, D. C.

BULLETIN 1. The volatile matter of coal, by H. C. Porter and F. K. Ovitz. 1910. 56 pp., 1 pl., 9 figs.

BULLETIN 2. North Dakota lignite as a fuel for power-plant boilers, by D. T. Randall and Henry Kreisinger. 1910. 42 pp., 1 pl., 7 figs.

BULLETIN 3. The coke industry of the United States as related to the foundry, by Richard Moldenke. 1910. 32 pp.

BULLETIN 4. Features of producer-gas power-plant development in Europe, by R. H. Fernald. 1910. 27 pp., 4 pls., 7 figs.

BULLETIN 5. Washing and coking tests of coal at Denver, Colo., July 1, 1908, to June 30, 1909, by A. W. Belden, G. R. Delamater, J. W. Groves, and K. M. Way. 1910. 62 pp., 1 fig.

BULLETIN 6. Coals available for the manufacture of illuminating gas, by A. H. White and Perry Barker, compiled and revised by H. M. Wilson. 1911. 77 pp., 4 pls., 12 figs.

BULLETIN 7. Essential factors in the formation of producer gas, by J. K. Clement, L. H. Adams, and C. N. Haskins. 1911. 58 pp., 1 pl., 16 figs.

BULLETIN 8. The flow of heat through furnace walls, by W. T. Ray and Henry Kreisinger. 1911. 32 pp., 19 figs.

BULLETIN 12. Apparatus and methods for the sampling and analysis of furnace gases, by J. C. W. Frazer and E. J. Hoffman. 1911. 22 pp., 6 figs.

BULLETIN 13. Résumé of producer-gas investigations, October 1, 1904, to June 30, 1910, by R. H. Fernald and C. D. Smith. 1911. 393 pp., 12 pls., 250 figs.

BULLETIN 14. Briquetting tests of lignite at Pittsburgh, Pa., 1908-9; with a chapter on sulphite-pitch binder, by C. L. Wright. 1911. 64 pp., 11 pls., 4 figs.

BULLETIN 16. The uses of peat for fuel and other purposes, by C. A. Davis. 1911. 214 pp., 1 pl., 1 fig.

BULLETIN 18. The transmission of heat into steam boilers, by Henry Kreisinger and W. T. Ray. 1912. 180 pp., 78 figs.

BULLETIN 19. Physical and chemical properties of the petroleums of the San Joaquin Valley, Cal., by I. C. Allen and W. A. Jacobs, with a chapter on analyses of natural gas from the southern California oil fields, by G. A. Burrell. 1911. 60 pp., 2 pls., 10 figs.

BULLETIN 23. Steaming tests of coals and related investigations, September 1, 1904, to December 31, 1908, by L. P. Breckenridge, Henry Kreisinger, and W. T. Ray. 1912. 380 pp., 2 pls., 94 figs.

BULLETIN 24. Binders for coal briquets, by J. E. Mills. 56 pp., 1 fig. Reprint of United States Geological Survey Bulletin 343.

BULLETIN 27. Tests of coal and briquets as fuel for house-heating boilers, by D. T. Randall. 44 pp., 3 pls., 2 figs. Reprint of United States Geological Survey Bulletin 366.

Bulletin 28. Experimental work conducted in the chemical laboratory of the United States fuel-testing plant at St. Louis, Mo., January 1, 1905, to July 31, 1906, by N. W. Lord. 51 pp. Reprint of United States Geological Survey Bulletin 323.

Bulletin 29. The effect of oxygen in coal, by David White. 80 pp., 3 pls. Reprint of United States Geological Survey Bulletin 382.

Bulletin 30. Briquetting tests at the United States fuel-testing plant at Norfolk, Va., 1907–8, by C. L. Wright. 41 pp., 9 pls. Reprint of United States Geological Survey Bulletin 385.

Bulletin 31. Incidental problems in gas-producer tests, by R. H. Fernald, C. D. Smith, J. K. Clement, and H. A. Grine. 29 pp., 8 figs. Reprint of United States Geological Survey Bulletin 393.

Bulletin 32. Commercial deductions from comparisons of gasoline and alcohol tests of internal-combustion engines, by R. M. Strong. 38 pp. Reprint of United States Geological Survey Bulletin 392.

Bulletin 33. Comparative tests of run-of-mine and briquetted coal on the torpedo boat *Biddle*, by W. T. Ray and Henry Kreisinger. 50 pp., 10 figs. Reprint of United States Geological Survey Bulletin 403.

Bulletin 34. Tests of run-of-mine and briquetted coal in a locomotive boiler, by W. T. Ray and Henry Kreisinger. 33 pp., 9 figs. Reprint of United States Geological Survey Bulletin 412.

Bulletin 35. The utilization of fuel in locomotive practice, by W. F. M. Goss. 29 pp., 8 figs. Reprint of United States Geological Survey Bulletin 402.

Bulletin 36. Alaskan coal problems, by W. L. Fisher. 1911. 32 pp., 1 pl.

Bulletin 37. Comparative tests of run-of-mine and briquetted coal on locomotives, including torpedo-boat tests, and some foreign specifications for briquetted fuel, by W. F. M. Goss. 58 pp., 4 pls., 35 figs. Reprint of United States Geological Survey Bulletin 363.

Bulletin 39. The smoke problem at boiler plants, a preliminary report, by D. T. Randall. 31 pp. Reprint of United States Geological Survey Bulletin 334, revised by S. B. Flagg.

Bulletin 40. The smokeless combustion of coal in boiler furnaces, with a chapter on central heating plants, by D. T. Randall and H. W. Weeks. 188 pp., 40 figs. Reprint of United States Geological Survey Bulletin 373, revised by Henry Kreisinger.

Bulletin 41. Government coal purchases under specifications, with analyses for the fiscal year 1909–10, by G. S. Pope, with a chapter on the fuel-inspection laboratory of the Bureau of Mines, by J. D. Davis. 1913. 97 pp., 3 pls.

Bulletin 43. Comparative fuel values of gasoline and denatured alcohol in internal-combustion engines, by R. M. Strong and Lauson Stone. 1912. 243 pp., 3 pls., 32 figs.

Bulletin 49. City smoke ordinances and smoke abatement, by S. B. Flagg. 1912. 55 pp.

Bulletin 54. Foundry cupola gases and temperatures, by A. W. Belden. 1913. 29 pp., 3 pls., 16 figs.

Bulletin 55. The commercial trend of the producer-gas power plant in the United States, by R. H. Fernald. 1913. 93 pp., 1 pl., 4 figs.

Bulletin 58. Fuel-briquetting investigations, July, 1904, to July, 1912, by C. L. Wright. 1913. 277 pp., 21 pls., 3 figs.

Bulletin 63. Sampling coal deliveries, and types of Government specifications for the purchase of coal, by G. S. Pope. 1913. 68 pp., 4 pls., 3 figs.

Technical Paper 1. The sampling of coal in the mine, by J. A. Holmes. 1911. 18 pp., 1 fig.

Technical Paper 2. The escape of gas from coal, by E. C. Porter and F. K. Ovitz. 1911. 14 pp., 1 fig.

Technical Paper 3. Specifications for the purchase of fuel oil for the Government, with directions for sampling oil and natural gas, by I. C. Allen. 1911. 13 pp.

TECHNICAL PAPER 5. The constituents of coal soluble in phenol, by J. C. W. Frazer and E. J. Hoffman. 1912. 20 pp., 1 pl.

TECHNICAL PAPER 8. Methods of analyzing coal and coke, by F. M. Stanton and A. C. Fieldner. 1913. 42 pp., 12 figs.

TECHNICAL PAPER 10. Liquefied products from natural gas; their properties and uses, by I. C. Allen and G. A. Burrell. 1912. 23 pp.

TECHNICAL PAPER 16. Deterioration and spontaneous combustion of coal in storage, a preliminary report, by H. C. Porter and F. K. Ovitz. 1912. 14 pp.

TECHNICAL PAPER 20. The slagging type of gas producer, with a brief report of preliminary tests, by C. D. Smith. 1912. 14 pp., 1 pl.

TECHNICAL PAPER 25. Methods for the determination of water in petroleum and its products, by I. C. Allen and W. A. Jacobs. 1912. 13 pp., 2 figs.

TECHNICAL PAPER 26. Methods of determining the sulphur content of fuels, especially petroleum products, by I. C. Allen and I. W. Robertson. 1912. 13 pp., 1 fig.

TECHNICAL PAPER 31. Apparatus for the exact analysis of flue gas, by G. A. Burrell and F. M. Seibert. 1913. 12 pp., 1 fig.

TECHNICAL PAPER 37. Heavy oil as fuel for internal combustion engines, by I. C. Allen. 1913. 36 pp.

TECHNICAL PAPER 49. The flash point of oils; methods and apparatus for its determination, by I. C. Allen and A. S. Crossfield. 1913. 31 pp., 2 figs.

TECHNICAL PAPER 55. The production and use of brown coal in the vicinity of Cologne, Germany, by C. A. Davis. 1913. 15 pp.

TECHNICAL PAPER 57. A preliminary report on the utilization of oil and natural gas in Wyoming, by W. R. Calvert, with a discussion of the suitability of natural gas for making gasoline, by G. A. Burrell. 1913. 23 pp.

TECHNICAL PAPER 72. Problems of the petroleum industry; results of conferences at Pittsburgh, Pa., August 1 and September 10, 1913, by I. C. Allen. 1914. 20 pp.

TECHNICAL PAPER 74. Physical and chemical properties of the petroleums of California, by I. C. Allen, W. A. Jacobs, A. S. Crossfield, and R. R. Mathews. 1914, 38 pp.

HODGE, J. M.
Geol. S
——— Su
River.
Includes a
area.
——— The Big
pp. 922
sections of
coal beds
MACFARLANE, G.
Min. Eng.,
distribution
measures of
MILLER, A. M. A
the western
for 1906 and
——— Coals of the
Ky. Geol. Sur
NORWOOD, C. J. A
for 1901 and
PETER, ROBERT.
tucky. Ky.

CLARK, W. B., AND
special publica
CLARK, W. B., and M
Geol. Surv., vol.

COOPER, W. F. Geol
Geol. Surv. Ann
LANE, A. C. Coal of
Surv., vol. 8, pt. 2.
——— Fifth annual re
Rept. for 1903,
——— Sixth annual re
Surv. Ann. Rept.

BROWN, C. S. Lignite

BARBOUR, E. H. Report
1907, pp. 349–364.
BUSH, B. F. The coal
165–179; Trans., vol
GORDON, C. H. A report
and Chariton Count
the physiographic
beds.

INDEX.

This index gives the names of places at or near which the samples of coal mentioned in this bulletin were collected. In addition, it gives the names of many coal beds, including names of geological significance as well as some that are merely local, and the names of most of the mines.

Attention is called to the fact that many beds opened by prospect pits, country banks, or even mines, especially beds in the Rocky Mountain province, have no names, even local ones. Moreover, such local names as "A," "B," "1," "2," "Upper," "Lower," have been omitted in the case of beds that have not been correlated with other beds similarly designated in the same State, the purpose in omitting such names being to reduce the length of the index and to avoid the confusion that would result from applying the same designation to different beds. Mines that in the text have no other title than a number, as "Mine No. 1," are not included, for the same reasons.

A. Page.

Abernant, Ala., coal from near, analysis of... 19
  description of... 150, 151
Abernant mine (Ala.). *See* Abernant, Ala.
Acme, Wyo., coal from near, analysis of... 139
  description of... 403, 404, 405
Acme No. 1 and No. 2 mines (Wyo.). *See* Acme, Wyo.
Acosta, Pa., coal from near, analysis of... 93, 94
  description of... 304, 305
Adamson, Okla., coal from near, analysis of.. 64
  description of... 252, 253
Albuquerque, N. Mex., coal from near, analysis of... 57
  description of... 235
Alderson, Okla., coal from near, analysis of.. 65
  description of... 253, 254
Alderson No. 5 and No. 38 mines (Okla.). *See* Alderson, Okla.
Algoma, W. Va., coal from near, analysis of. 114, 115
  description of... 352, 353
Allen bed, Colo., coal from, analysis of... 25
  description of... 168, 169
Allison prospect (Mont.), coal from, analysis of... 55
  description of... 229
Allport mine (Pa.), coal from, analysis of.... 69
  description of... 261–263
Amor, N. Dak., coal from near, analysis of... 59
  description of... 242, 243
Amsterdam, Mo., coal from near, analysis of.. 42, 43
  description of... 209
Amsterdam, Ohio, coal from near, analysis of. 61
  description of... 246, 247
Amsterdam mine (Ohio). *See* Amsterdam, Ohio.
Anderson bed, Oreg., coal from, analysis of.. 66, 67
  description of... 255, 256, 257
  sections of... 256, 257
Anderson mine (Mo.), coal from, analysis of.. 49
  description of... 218, 219

Page.

Angel bed, Tenn., coal from, analysis of... 101
  description of... 330
Antelope, Mont., coal from near, analysis of.. 55
  description of... 230
Antelope No. 3 mine (Wyo.), coal from, analysis of... 146
  description of... 415, 416
Antelope No. 4 mine (Wyo.), coal from, analysis of... 146
  description of... 415, 416
Anthracite No. 4 mine (N. Mex.), coal from, analysis of... 59
  description of... 240
Anthracite Ridge, Alaska, coal from, analysis of... 22
  description of... 156, 157
Ashford, Wash., coal from near, analysis of.. 108
  description of... 341
Astrope mine (Mont.), coal from, analysis of.. 56
  description of... 232
Avella, Pa., coal from near, analysis of... 97
  description of... 311, 312
Avoca, N. Dak., coal from near, analysis of.. 60
  description of... 244
Axial, Colo., coal from near, analysis of... 33
  description of... 185, 186

B.

B bed, Pa., coal from, analysis of... 69, 71, 72, 73, 74, 75, 76, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 95
  description of. 263, 266, 267, 268, 269, 270, 271, 272, 273, 276, 277, 278, 279, 280, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 307
  sections o... 263, 266, 267, 268, 269, 270, 271, 273, 276, 278, 279, 280, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 294, 295, 296, 297, 298, 299, 300, 307

INDEX.

This index gives the names of places at or near which the samples of coal mentioned in this bulletin were collected. In addition, it gives the names of many coal beds, including names of geological significance as well as some that are merely local, and the names of most of the mines.

Attention is called to the fact that many beds opened by prospect pits, country banks, or even mines, especially beds in the Rocky Mountain province, have no names, even local ones. Moreover, such local names as "A," "B," "1," "2," "Upper," "Lower," have been omitted in the case of beds that have not been correlated with other beds similarly designated in the same State, the purpose in omitting such names being to reduce the length of the index and to avoid the confusion that would result from applying the same designation to different beds. Mines that in the text have no other title than a number, as "Mine No. 1," are not included, for the same reasons.

A. Page.

Abernant, Ala., coal from near, analysis of... 19
  description of........................ 150,151
Abernant mine (Ala.). *See* Abernant, Ala.
Acme, Wyo., coal from near, analysis of..... 139
  description of.................. 403,404,405
Acme No. 1 and No. 2 mines (Wyo.). *See* Acme, Wyo.
Acosta, Pa., coal from near, analysis of...... 93,94
  description of...................... 304,305
Adamson, Okla., coal from near, analysis of.. 64
  description of...................... 252,253
Albuquerque, N. Mex., coal from near, analysis of.............................. 57
  description of........................ 235
Alderson, Okla., coal from near, analysis of.. 65
  description of...................... 253,254
Alderson No. 5 and No. 38 mines (Okla.). *See* Alderson, Okla.
Algoma, W. Va., coal from near, analysis of. 114,115
  description of...................... 352,353
Allen bed, Colo., coal from, analysis of....... 25
  description of...................... 168,169
Allison prospect (Mont.), coal from, analysis of............................ 55
  description of........................ 229
Allport mine (Pa.), coal from, analysis of.... 69
  description of...................... 261-263
Amor, N. Dak., coal from near, analysis of... 59
  description of...................... 242,243
Amsterdam, Mo., coal from near, analysis of.. 42,43
  description of........................ 209
Amsterdam, Ohio, coal from near, analysis of. 61
  description of...................... 246,247
Amsterdam mine (Ohio). *See* Amsterdam, Ohio.
Anderson bed, Oreg., coal from, analysis of.. 66,67
  description of................. 255,256,257
    sections of...................... 256,257
Anderson mine (Mo.), coal from, analysis of.. 49
  description of...................... 218,219

Page.

Angel bed, Tenn., coal from, analysis of..... 101
  description of........................ 320
Antelope, Mont., coal from near, analysis of.. 55
  description of........................ 230
Antelope No. 3 mine (Wyo.), coal from, analysis of.............................. 146
  description of...................... 415,416
Antelope No. 4 mine (Wyo.), coal from, analysis of.............................. 146
  description of...................... 415,416
Anthracite No. 4 mine (N. Mex.), coal from, analysis of......................... 59
  description of........................ 240
Anthracite Ridge, Alaska, coal from, analysis of.............................. 22
  description of...................... 156,157
Ashford, Wash., coal from near, analysis of.. 108
  description of........................ 341
Astrope mine (Mont.), coal from, analysis of.. 56
  description of........................ 232
Avella, Pa., coal from near, analysis of...... 97
  description of...................... 311,312
Avoca, N. Dak., coal from near, analysis of.. 60
  description of........................ 244
Axial, Colo., coal from near, analysis of...... 33
  description of...................... 185,186

B.

B bed, Pa., coal from, analysis of............ 69, 71, 72, 73, 74, 75, 76, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 95
  description of. 263, 266, 267, 268, 269, 270, 271, 272, 273, 276, 277, 278, 279, 280, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 307
  sections o......................... 263, 266, 267, 268, 269, 270, 271, 273, 276, 278, 279, 280, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 294, 295, 296, 297, 298, 299, 300, 307

Page.
Bainville, Mont., coal from near, analysis of.. 55
description of.... 230,231
Baird, Pa., coal from near, analysis of....... 87,88
description of.... 292
Banner mine (Ala.), coal from, analysis of.... 17
description of.... 147
Barnesboro, Pa., coal from near, analysis of.... 69,70,71
description of.... 261,262,263,264,265,266
Barnett Creek, Alaska, coal from near, analysis of.... 19
description of.... 151,152
Battle Era mine (Colo.), coal from, analysis of.... 23
description of.... 165
Bear Creek, Mont., coal from near, analysis of.... 52,53
description of.... 222,223,224
Beaverdale, Pa., coal from near, analysis of.. 71
description of.... 286,287
Beckley bed, W. Va., coal from, analysis of.. 127, 128,129,130,131
description of.... 378, 379,380,381,382,383,384,385,386
sections of..... 378,379,380,381,382,383,384,385
Belgon mine (Mont.), coal from, analysis of.. 56
description of.... 222,223
Belle Valley, Ohio, coal from near, analysis of. 63
description of.... 251
Belleville No. 6 bed, Ill., coal from, analysis of.... 26,27
description of.... 196,197,198
sections of.... 197,198
See No. 6 bed, Ill.
Belmont No. 1 mine (Pa.), coal from, analysis of.... 93,94
description of.... 204,205
Belshe mine (Wyo.), coal from, analysis of... 133
description of.... 290,291
Bennett, Colo., coal from near, analysis of... 23
description of.... 163
Bens Creek, Pa., coal from near, analysis of.. 72
description of.... 287,288
Bens Creek No. 1 mine (Pa.), coal from, analysis of.... 72
description of.... 287
Bergholz, Ohio, coal from near, analysis of... 61
description of.... 247
Berlin, Pa., coal from near, analysis of....... 94
description of.... 205
Berwind bed, Colo., coal from, analysis of... 20,22
description of.... 178,179,183,184
sections of.... 178,183
Bevier bed, Kans., coal from, analysis of..... 28,29
description of.... 202,203
Bevier bed, Mo., coal from, analysis of...... 45,50
description of.... 207,211,212,219,220
Bevier mine (Ky.), coal from, analysis of.... 40
description of.... 205,206
Big bed, Ala., coal from, analysis of......... 17
description of.... 147
sections of.... 147
Big Bend No. 1 mine (Pa.), coal from, analysis of.... 82
description of.... 282,283
Big Bend No. 6 mine (Pa.), coal from, analysis of.... 82,83
description of.... 283
Big Four, W. Va., coal from near, analyses of. 115
description of.... 353,354
Bighorn, Mont., coal from near, analysis of.. 55
description of.... 223
Big Horn mine (Wyo.), coal from, analysis of.... 134,135,136
description of.... 294,295
Big Sandy, Mont., coal from near, analysis of. 54
description of.... 224,225
Big Stick mine (W. Va.), coal from, analysis of 127
description of.... 378,379
Black Diamond mine, coal from, analysis of.... (Colo.) 25, (Wyo.) 139
description of..... (Colo.) 182, (Wyo.) 401
Blackrock, N. Mex., coal from near, analysis of.... 89
description of.... 240
Blacksmith mine (N. Mex.), coal from, analysis of.... 89
description of.... 241
Blair mine (Mont.), coal from, analysis of... 55
description of.... 229,230
Blossburg, N. Mex., coal from near, analysis of.... 87
description of.... 236
Blue Bell mine (Utah), coal from, analysis of. 165
description of.... 339
Blue Jay No. 4 mine (W. Va.), coal from, analysis of.... 128
description of.... 379,380
Boardman, Pa., coal from near, analysis of.. 85,86
description of.... 289
Bolen-Darnall No. 4 mine (Okla.), coal from, analysis of.... 65
description of.... 254
Bolling mine (Va.), coal from, analysis of... 107
description of.... 335
Bowie, Colo., coal from near, analysis of..... 24
description of.... 164,165
Braxton, W. Va., coal from near, analysis of. 110
description of.... 344
Braxton mine (W. Va.). *See* Braxton, W. Va.
Briceville, Tenn., coal from near, analysis of. 101
description of.... 319
Brilliant, Ohio, coal from near, analysis of... 62
description of.... 248
Brisbin, Pa., coal from near, analysis of...... 88
description of.... 289,290
Broken Arrow bed, Ala., coal from, analysis of 18
description of.... 150
section of.... 150
Brookfield, Mo., coal from near, analysis of.. 48,49
description of.... 217
Brown mine (W. Va.), coal from, analysis of.... 113
description of.... 350,351
Brown No. 1 mine (Mo.), coal from, analysis of 51
description of.... 221
Brown Bear mine (Idaho), coal from, analysis of.... 36
description of.... 196,198

Page.

Browning, Mont., coal from near, analysis of. 55
  description of 229
Browning mine (Utah), coal from, analysis of. 104
  description of 326
Bruceton, Pa., coal from near, analysis of.... 67
  description of 257, 258
Bruegger mine, coal from, analysis of.... (Mont.) 56, (N. Dak.) 60
  description of.. (Mont.) 231, (N. Dak.) 244
Buchannon prospect (Wash.), coal from, analysis of 107
  description of 337
Bucher mine (Pa.), coal from, analysis of.... 86
  description of 290, 291
Buffalo, S. Dak., coal from near, analysis of.. 100
  description of 316, 317
Buffalo mine (W. Va.), coal from, analysis of. 114
  description of 351
Buffalo, Wyo., coal from near, analysis of.... 137
  description of 397, 398
Busby No. 5 mine (Okla.), coal from, analysis of 65, 66
  description of 254, 255
Butterfield mine (Mont.), coal from, analysis of 56
  description of 231

C.

C bed, Pa., coal from, analysis of...... 75, 77, 87, 88
  description of 272, 275, 292, 293
  sections of 292, 293
C'bed, Pa., coal from, analysis of 77, 79, 80, 93, 94, 95, 96, 97
  description of 275, 277, 278, 279, 304, 305, 306, 307, 308, 309, 310, 311
  sections of 272, 275, 277, 278, 279, 293, 304, 308, 310, 311
Cabbage Run mine (Ohio), coal from, analysis of 62
  description of 249
Cainesville, Mo., coal from near, analysis of.. 45
  description of 212, 213
Cainesville bed, Mo. *See* Cainesville, Mo.
Cainesville mine (Mo.). *See* Cainesville, Mo.
Calhan, Colo., coal from near, analysis of..... 24
  description of 165
Calhoun, Mo., coal from near, analysis of..... 46
  description of 213
Cambria, Wyo., coal from near, analysis of... 146
  description of 415, 416
Cambria No. 3 mine (Pa.), coal from, analysis of 68, 69
  description of 260, 261
Cameron mine (Mont.), coal from, analysis of. 54
  description of 225, 226
Cantine No. 3 mine (Ill.), coal from, analysis of 36
  description of 196, 197
Caperton, W. Va., coal from near, analysis of. 111
  description of 345, 346
Carbon Hill mine (Va.), coal from, analysis of. 106
  description of 333, 334
Carbon Mountain, Alaska, coal from, analysis of 19
  description of 153
Carney bed, Wyo., coal from, analysis of.... 139, 140, 141, 142
  description of 403, 404, 405, 406
  sections of 403, 404, 405
Carney mines (Wyo.), coal from, analysis of 140, 141
  description of 405, 406
Carneyville, Wyo. *See* Carney mines.
Carrolltown Road, Pa., coal from near, analysis of 73
  description of 268, 269
Carson No. 1 mine (Mo.), coal from, analysis of 50
  description of 219
Carter bed, Oreg., coal from, analysis of....... 66
  description of 256
  section of 256
Casper, Wyo., coal form near, analysis of.... 137, 138
  description of 398, 399, 400
Casper mine (Utah), coal from, analysis of.... 104
  description of 327
Catsburg mine (Pa.), coal from, analysis of... 98, 99
  description of 313, 314
Central City, Ky., coal from near, analysis of.. 40
  description of 205
Central mine (Ky.), coal from, analysis of..... 40
  description of 205
Chandler, Colo., coal from near, analysis of.... 24, 25
  description of 167
Chandler mine (Colo.). *See* Chandler, Colo.
Chickaloon Creek, Alaska, coal from near, analysis of 22, 23
  description of 157, 158
Chignik Bay, Alaska, coal from near, analysis of 19
  description of 151
Cincinnati mine (Pa.), coal from, analysis of.. 98
  description of 313
Cirrus No. 2 mine (W. Va.), coal from, analysis of 115
  description of 353, 354
Clear Creek, Alaska, coal from near, analysis of 20
  description of 153
  branch of, coal from near, analysis of...... 19
  description of 153
Cleaton, Ky., coal from near, analysis of...... 40
  description of 205, 206
Cleveland, Mont., coal from near, analysis of.. 52
  description of 221, 222
Clinton, Mo., coal from near, analysis of....... 46, 47
  description of 214, 215
Clintwood, Va., coal from near. *See* Clintwood bed, Va.
Clintwood bed, Va., coal from, analysis of.... 105
  description of 332, 333
  sections of 332, 333
Clymer, Pa., coal from near, analysis of....... 91
  description of 299, 300
Coal Branch mine (Ala.). *See* Coal City bed.
Coal City, Ala. *See* Coal City bed.
Coal City bed, Ala., coal from, analysis of.... 18
  description of 149
  section of 149
Coal Creek, Alaska, coal from near, analysis of 23
  description of 158, 159

Page.
Coal Creek bed, Tenn., coal from, analysis of.. 101
description of.......... 319
sections of.......... 319
Coaldale, Nev., coal from near, analysis of.... 57
description of.......... 234, 235
Coalmont, Colo., coal from near, analysis of.. 26
description of.......... 171, 172
Coal Ridge mine (Mont.), coal from, analysis of.......... 56
description of.......... 233
Coalville, Utah, coal from, analysis of.......... 105
description of.......... 329, 330
Cody, Wyo., coal from near, analysis of....... 138
description of.......... 400, 401
Cokedale, Colo., coal from near, analysis of... 28
description of.......... 176
Cokedale mine (Colo.). *See* Cokedale, Colo.
Colliers, W. Va., coal from near, analysis of.... 111
description of.......... 344, 345
Colliery No. 14 mine (Pa.), coal from, analysis of.......... 93
description of.......... 303
Collinsville, Ill., coal from near, analysis of.. 36
description of.......... 196, 197
Collom mines (Colo.), coal from, analysis of. 33
description of.......... 185, 186
Colorado No. 5 mine (Pa.), coal from, analysis of.......... 88, 89
description of.......... 293, 294
Columbia, Mo., coal from near, analysis of... 44, 45
description of.......... 211, 212
Colver, Pa., coal from near, analysis of....... 73, 74
description of.......... 269, 270
Colver mine (Pa.). *See* Colver, Pa.
Commercial No. 3 mine (Pa.), coal from, analysis of.......... 83
description of.......... 284
Commercial No. 4 mine (Pa.), coal from, analysis of.......... 83
description of.......... 284, 285
Commercial No. 5 mine (Pa.), coal from, analysis of.......... 84
description of.......... 285, 286
Confluence, Pa., coal from near, analysis of.. 94
description of.......... 306
Consolidation No. 204 mine (Ky.), coal from, analysis of.......... 39
description of.......... 204
Consolidation No. 112 mine (Pa.), coal from, analysis of.......... 96
description of.......... 309
Consolidation No. 113 mine (Pa.), coal from, analysis of.......... 96
description of.......... 309, 310
Cook mine (Mont.), coal from, analysis of.... 52
description of.......... 221, 222
Cook & White bed, N. Mex., coal from, analysis of.......... 59
description of.......... 241
section of.......... 241
Cornrike mine (Colo.), coal from, analysis of.......... 35
description of.......... 192, 193
Coronet No. 3 mine (Pa.), coal from, analysis of.......... 94
description of.......... 305
Cortez, Colo., coal from near, analysis of..... 33, 34
description of.......... 187, 188, 189, 190
Cortez mine (Colo.), coal from, analysis of.... 33
description of.......... 187
Cox mine (Colo.), coal from, analysis of...... 28, 29
description of.......... 177, 178
Craig, Colo., coal from near, analysis of....... 33
description of.......... 186, 187
Craig, Okla., coal from near, analysis of...... 65
description of.......... 254
Crandall No. 1 mine (Mo.), coal from, analysis of.......... 48
description of.......... 217
Crane Creek No. 1 mine (W. Va.), coal from, analysis of.......... 124
description of.......... 372, 373
Crane Creek No. 2 mine (W. Va.), coal from, analysis of.......... 124, 125
description of.......... 372, 375
Creighton, Pa., coal from near, analysis of... 68
description of.......... 259, 260
Crosby, Wyo., coal from near, analysis of.... 134, 135, 136
description of.......... 394, 395
Cross Mountain No. 1 mine (Tenn.), coal from, analysis of.......... 101
description of.......... 319
Crystal, W. Va., coal from near, analysis of.. 122
description of.......... 366
Culbertson, Mont., coal from near, analysis of. 56
description of.......... 231, 232
Cummings mine (Utah), coal from, analysis of.......... 105
description of.......... 332
Cunningham claims (Alaska), coal from, analysis of.......... 19, 20, 21
description of.......... 151, 152, 153, 155, 156
Cut Bank, Mont., coal from near, analysis of. 55
description of.......... 229
Cymbria mine (Pa.), coal from, analysis of.. 69
description of.......... 263
Cymbria No. 1 mine (Pa.), coal from, analysis of.......... 70
description of.......... 263, 264
Cymbria No. 2½ mine (Pa.), coal from, analysis of.......... 70, 71
description of.......... 265

D.

D bed, Pa., coal from, analysis of.......... 68, 69, 70, 71, 76, 77, 81, 89, 93, 95
description of.......... 259, 260, 261, 262, 263, 264, 265, 266, 273, 274, 275, 280, 281, 282, 294, 295, 302, 303, 306
sections of.......... 259, 262, 264, 265, 274, 281, 294, 302, 303, 306
Dante, Va., coal from near, analysis of...... 106
description of.......... 334, 335
Darms mine (Nev.), coal from, analysis of... 57
description of.......... 234, 235
Davy bed, W. Va., coal from, analysis of.... 117
description of.......... 358, 359
sections of.......... 360
Davy-Pocahontas No. 1 mine (W. Va.), coal from, analysis of.......... 117
description of.......... 358, 359

Page.
Davy-Pocahontas No. 2 mine (W. Va.), coal from, analysis of.................... 117
description of....................... 358, 359
Dawson, N. Mex., coal from near, analysis of.. 57
description of....................... 235, 236
Dawson No. 2 mine (N. Mex.). *See* Dawson, N. Mex.
Dayton, Tenn., coal from near, analysis of... 102
description of....................... 322, 323
Deepwater, Mo., coal from near, analysis of.. 47
description of....................... 215, 216
Delagua, Colo., coal from near, analysis of... 28
description of....................... 177
Delagua mine (Colo.). *See* Delagua, Colo.
Dempsey mine (Mont.), coal from, analysis of. 56
description of....................... 231
Diamond mine (Wyo.), coal from, analysis of. 132
description of....................... 387, 388
Dickey No. 1 pit (Mo.), coal from, analysis of. 47
description of....................... 215, 216
Dickie No. 1 prospect (Wyo.), coal from, analysis of....................... 137
description of....................... 397
Dietz, Wyo., coal from near, analysis of..... 141
description of....................... 406, 407
Dietz No. 4 mine (Wyo.). *See* Dietz, Wyo.
Dolorés, Colo., coal from near, analysis of.... 35
description of....................... 190, 191
Dominguez, Colo., coal from near, analysis of. 24
description of....................... 165
Dorrance mine (Pa.), coal from, analysis of.. 93
description of....................... 304
Douglas, Wyo., coal from near, analysis of... 132
description of....................... 387
Dugger, Ind., coal from near, analysis of..... 37
description of....................... 199, 200
Duggins bed, Utah, coal from, analysis of.... 104
description of....................... 329
section of....................... 329
Dunlo, Pa., coal from near, analysis of....... 74, 75
description of....................... 270, 271
Dunloop, W. Va., coal from near, analysis of. 111
description of....................... 346, 347
Dunn Loop No. 2 mine (W. Va.). *See* Dunloop, W. Va.
Dunmore, Pa., coal from near, analysis of.... 93
description of....................... 303
Dunmore No. 2 bed, Pa. *See* Dunmore, Pa.
Durango, Colo., coal from near, analysis of... 27
description of....................... 174
Durkin prospect (N. Dak.), coal from, analysis of....................... 59
description of....................... 242, 243

E.

E bed, Pa., coal from, analysis of............ 68, 69, 70, 71, 86, 92, 93, 94, 99
description of................. 259, 260, 261, 262, 263, 264, 265, 290, 300, 301, 302, 305, 315
sections of..... 259, 261, 262, 265, 290, 301, 306, 315
Eagle mine, coal from, analysis of.......(Pa.), 95; (Wyo.), 139
description of.......(Pa.), 306; (Wyo.), 402
Eastern Ohio mine (Ohio), coal from, analysis of....................... 61
description of....................... 246, 247

Page.
East Wiley mine (Wyo.), coal from, analysis of....................... 139
description of....................... 402
Eclipse No. 1 mine (Okla.), coal from, analysis of....................... 64
description of....................... 252, 253
Edgewater mine (Ky.), coal from, analysis of. 41
description of....................... 207
Edlund bed, Wash., coal from, analysis of... 108
description of....................... 340
Elberfeld, Ind., coal from near, analysis of... 37
description of....................... 200
Elberfeld mine (Ind.). *See* Elberfeld, Ind.
Electric mine (Pa.), coal from, analysis of... 84, 85
description of....................... 286, 287
Elizabeth mine (Ohio), coal from, analysis of 61
description of....................... 247
Elkins No. 1 mine (W. Va.), coal from, analysis of....................... 126, 127
description of....................... 377
Elkins No. 6 mine (W. Va.), coal from, analysis of....................... 127
description of....................... 377, 378
Elk Lick, Pa., coal from near, analysis of.... 95
description of....................... 306
Elkol, Wyo., coal from near, analysis of...... 145
description of....................... 413
Elkol mine (Wyo.). *See* Elkol, Wyo.
Ellensburg, Wash., coal from near, analysis of 107
description of....................... 337, 338
El Mora, Pa., coal from near, analysis of.... 75
description of....................... 271, 272
Elverton, W. Va., coal from near, analysis of.. 112
description of....................... 347, 348
Elverton mine (W. Va.). *See* Elverton, W. Va.
Emery, Utah, coal from near, analysis of...... 104
description of.................. 326, 327, 328
Empire A mine (Pa.), coal from, analysis of. 71
description of....................... 265, 266
Empire M (McKean) mine (Pa.), coal from, analysis of....................... 91
description of....................... 299
Empire R mine (Pa.), coal from, analysis of....................... 91
description of....................... 299, 300
Engle Mine (Pa.), coal from, analysis of...... 95
description of....................... 306
Engle-Starkville bed, Colo., coal from, analysis of....................... 29, 34
description of.............. 179, 180, 182, 183
sections of....................... 179, 182
Ephraims Creek mine (W. Va.), coal from, analysis of....................... 114
description of....................... 351
Experimental mine (Pa.), coal from, analysis of....................... 67
description of....................... 257, 258

F.

Fairfax, Wash., coal from near, analysis of.. 108, 109
description of....................... 341, 342
Fairfield mine (Colo.), coal from, analysis of.. 35
description of....................... 193
Fairmount No. 2 mine (Pa.), coal from, analysis of....................... 89
description of....................... 294, 295

Page.
Figart, Pa., coal from near, analysis of....... 75
description of........................ 272
Finleyville, Pa., coal from near, analysis of.... 98
description of........................ 313
Fire Creek bed, W. Va., coal from, analysis of. 114
description of........................ 351
section of............................ 351
Flanigan prospect (Oreg.), coal from, analysis of.......................... 66
description of........................ 255
Flatgap, Va., coal from near, analysis of.... 39, 107
description of.................. 208, 335, 336
Flathead River, North Fork of, Mont., coal from near, analysis of............. 55
description of........................ 227
Fleming Pit No. 1 (Mo.), coal from, analysis of 43
description of........................ 210
Forbes, Colo., coal from near, analysis of...... 28, 29
description of...................... 177, 178
Forbes No. 9 mine (Colo.) *See* Forbes, Colo.
Forge Slope No. 1 mine (Pa.), coal from, analysis of.......................... 79
description of...................... 277, 278
Franklin, Kans., coal from near, analysis of... 37
description of...................... 200, 201
Fremont, Utah, coal from near, analysis of.... 104
description of........................ 328
Frick No. 2 mine (Pa.), coal from, analysis of.. 75
description of........................ 272
Froid, Mont., coal from near, analysis of...... 56
description of........................ 232
Frontier, Wyo., coal from near, analysis of.... 145
description of...................... 413, 414
Fuller, Kans., coal from near, analysis of.... 38
description of........................ 201
Fulton, Mo., coal from near, analysis of...... 45
description of........................ 212
Fulton bed, Pa., coal from, analysis of....... 90, 91
description of...................... 297, 298
sections of......................... 297, 298

G.

Gale Creek mine (Wash.), coal from, analysis of........................... 109, 110
description of...................... 343, 344
Gardiner, N. Mex., coal from near, analysis of. 57
description of........................ 236
Gardiner No. 1 mine (N. Mex.). *See* Gardiner, N. Mex.
Gayton, Va., coal from near, analysis of...... 106
description of...................... 333, 334
Gebo bed, Wyo., coal from, analysis of. 134, 135, 136
description of.................. 394, 395, 396
sections of......................... 394, 395
Gebo mine (Wyo.), coal from, analysis of.. 136, 137
description of...................... 395, 396
Geltz mine (N. Dak), coal from, analysis of.. 60
description of........................ 245
Glacier Creek, Alaska, coal from near, analysis of.......................... 20
description of........................ 153
Glamorgan, Va., coal from near. *See* Glamorgan bed, Va.
Glamorgan bed, Va., coal from, analysis of... 107
description of...................... 335, 336
sections of........................... 335
Glamorgan No. 3 mine (Va.). *See* Glamorgan bed, Va.
Glen Campbell, Pa., coal from near, analysis of.............................. 92
description of...................... 300, 301
Glendive, Mont., coal from near, analysis of. 54
description of........................ 226
Glenrock, Wyo., coal from near, analysis of.. 132
description of........................ 387
Godfrey mine (W. Va.), coal from, analysis of.............................. 122
description of........................ 368
Goodwill, W. Va., coal from near, analysis of............................ 122, 123
description of.................. 369, 370, 371
Goodwill mine (W. Va.). *See* Goodwill, W. Va.
Goucher No. 2 mine (Ohio), coal from, analysis of.......................... 62
description of........................ 248
Graham, Ky., coal from near, analysis of.... 41
description of........................ 206
Grand Junction, Colo., coal from near, analysis of.......................... 33
description of...................... 184, 185
Grand Ridge, Wash., coal from near, analysis of.............................. 107
description of........................ 336
Grand Ridge mine (Wash.). *See* Grand Ridge, Wash.
Grassy Run No. 1 mine (Pa.), coal from, analysis of........................ 95
description of........................ 306
Green mine (Utah), coal from, analysis of.... 105
description of........................ 330
Greensburg, Pa., coal from near, analysis of.. 99
description of........................ 314
Greybull mine (Wyo.), coal from, analysis of. 139
description of........................ 401
Guion mine (Pa.), coal from, analysis of..... 89
description of........................ 295
Gunn, Wyo., coal from near, analysis of..... 144
description of........................ 411

H.

Haden, Idaho, coal from near, analysis of.... 36
description of...................... 195, 196
Hale mine (Tenn.), coal from, analysis of... 101
description of........................ 320
Hale prospect (Tenn.), coal from, analysis of. 101
description of........................ 321
Haller mine (Colo.), coal from, analysis of.... 35
description of........................ 191
Hamilton prospect (Colo.), coal from, analysis of.......................... 33
description of...................... 187, 188
Hammond prospect (Oreg.), coal from, analysis of.......................... 66
description of........................ 256
Hanna, Utah, coal from near, analysis of..... 105
description of...................... 331, 332
Harmon bed, N. Dak., coal from, analysis of. 59
description of........................ 243
section of............................ 243
Harney Creek mine (Wyo.), coal from, analysis of.......................... 132
description of...................... 388, 389

Page.

- Harrisburg, Ill., coal from near, analysis of 37
  - description of 198, 199
- Hartline No. 1 mine (Alaska), coal from, analysis of 20
  - description of 154
- Hartline No. 2 mine (Alaska), coal from, analysis of 20
  - description of 154
- Hartline No. 3 mine (Alaska), coal from, analysis of 20
  - description of 154
- Hartline No. 4 mine (Alaska), coal from, analysis of 20
  - description of 154
- Hartline No. 5 mine (Alaska), coal from, analysis of 20
  - description of 154
- Hartline No. 6 mine (Alaska), coal from, analysis of 21
  - description of 154
- Hartline No. 7 mine (Alaska), coal from, analysis of 21
  - description of 155
- Hartshorne bed, Okla., coal from, analysis of 64
  - description of 252
  - sections of 252
- Hastings, Colo. *See* Hastings bed, Colo.
- Hastings, Pa., coal from near, analysis of 76, 77
  - description of 273, 274, 275
- Hastings bed, Colo., coal from, analysis of 29
  - description of 178, 179
  - sections of 178
- Hastings mine (Colo.). *See* Hastings bed, Colo.
- Havaco (formerly Jed) mine (W. Va.), coal from, analysis of 116
  - description of 355
- Hawks Nest, W. Va., coal from near, analysis of 112
  - description of 348, 349
- Haynes, N. Dak., coal from near, analysis of 59
  - description of 242
- Haynes prospect (Wyo.), coal from, analysis of 132
  - description of 388
- Heber, Utah, coal from near, analysis of 105
  - description of 332
- Hell Gate mine (Mont.), coal from, analysis of 55
  - description of 227, 228
- Hellier, Ky., coal from near, analysis of 41
  - description of 207
- Henriette mine (Pa.), coal from, analysis of 74, 75
  - description of 270, 271
- Henry mine (Idaho), coal from, analysis of 35
  - description of 194, 195
- Herbert, Tenn., coal from near, analysis of 101
  - description of 319, 320
- Herrin bed, Ill., coal from, analysis of 36, 37
  - description of 196, 197, 198
  - sections of 197, 198
- Hesperus, Colo., coal from near, analysis of 27
  - description of 174, 175
- Hesperus mine (Colo.). *See* Hesperus, Colo.
- Hiawatha, Utah, coal from near, analysis of 103
  - description of 323

Page.

- Hiawatha No. 1 and No. 2 mines (Utah). *See* Hiawatha, Utah.
- Hickey mine (Wyo.), coal from, analysis of 133
  - description of 391, 392
- Higho, Colo., coal from near, analysis of 26
  - description of 172
- Hilger, Mont., coal from near, analysis of 54
  - description of 226, 227
- Hillis prospect (Oreg.), coal from, analysis of 66
  - description of 256
- Hilton mine (S. Dak.), coal from, analysis of 100
  - description of 316
- Hite mine (Pa.), coal from, analysis of 68
  - description of 259, 260
- Hogan prospect (Utah), coal from, analysis of 104
  - description of 328
- Holen mine (N. Mex.), coal from, analysis of 59
  - description of 241
- Holmes mine (N. Mex.), coal from, analysis of 57
  - description of 235
- Holsopple, Pa., coal from near, analysis of 95
  - description of 307, 308
- Homer City, Pa., coal from near, analysis of 92, 93
  - description of 301, 302
- Honolulu prospect (Oreg.), coal from, analysis of 67
  - description of 257
- Hopedale, Ohio, coal from near, analysis of 62
  - description of 248, 249
- Hopewell, Pa., coal from near, analysis of 68, 69
  - description of 260, 261
- Hopkins mine (W. Va.), coal from, analysis of 132
  - description of 386
- Horseshoe Bend, Idaho, coal from near, analysis of 35
  - description of 194, 195
- Horseshoe mine (Idaho), coal from, analysis of 36
  - description of 196
- Hotcoal, W. Va., coal from near, analysis of 127
  - description of 378, 379
- Hudson, Wyo., coal from near, analysis of 133, 134
  - description of 391, 392, 393, 394
- Huger, W. Va., coal from near, analysis of 115
  - description of 354, 355
- Hughey prospect (Wyo.), coal from, analysis of 141
  - description of 407
- Hume, Mo., coal from near, analysis of 43
  - description of 209, 210
- Hunts mine (Alaska), coal from analysis of 21
  - description of 154
- Huntsville, Mo., coal from near, analysis of 50
  - description of 219, 220
- Hurst No. 1 mine (Mo.)., coal from, analysis of 47
  - description of 216
- Hutchinson mine (W. Va.), coal from, analysis of 121
  - description of 366, 367

I.

- Indian mine (Wyo.), coal from, analysis of 133, 134
  - description of 392
- Indiana No. 6 mine (Pa.), coal from, analysis of 92
  - description of 300, 301

Page.
Indio mine (Ala.), coal from, analysis of..... 17
description of........................ 148
Inez, Wyo., coal from near, analysis of....... 132
description of...................... 387, 388
Inez mine (Wyo.), coal from, analysis of..... 132
description of........................ 388

J.

Jackson mine (Colo.), coal from, analysis of.. 34
description of...................... 188, 189
Jagger bed, Ala., coal from, analysis of....... 19
description of..................... 150, 151
section of................................ 150
James mine (Colo.), coal from, analysis of.... 33
description of...................... 185, 186
Jed, W. Va., coal from near, analysis of...... 116
description of........................ 355
Jed mine (W. Va.). *See* Havaco mine, W. Va.
Jefferson bed, Ala., coal from, analysis of.... 17
description of........................ 148
sections of.............................. 148
Jenkinjones, W. Va., coal from near, analysis of................................ 116
description of...................... 355, 356
Jenkins, Ky., coal from near, analysis of..... 39, 40
description of...................... 204, 205
Jerome, Pa., coal from near, analysis of...... 95
description of...................... 308, 309
Jerome No. 2 mine (Pa.). *See* Jerome, Pa.
John's Branch mine (W. Va.), coal from, analysis of............................ 119
description of........................ 362
Johnstown, Pa., coal from near, analysis of.. 77
description of........................ 275
Jones bed, Mont., coal from, analysis of...... 56
description of........................ 233
Jones mine, coal from, analysis of..... (Mont.), 56; (N. Dak.), 60; (S. Dak.), 100
description of.............. (N. Dak.), 244; (Mont.), 233; (S. Dak.), 318
Jones No. 1 mine (Mo.), coal from, analysis of. 51
description of........................ 221
Jordan bed, Mo., coal from, analysis of....... 47
description of.................. 214, 215, 216

K.

Kaycee, Wyo., coal from near, analysis of.... 138
description of........................ 400
Kay Moor, W. Va., coal from near, analysis of................................ 113
description of...................... 349, 350
Kay Moor No. 1 and No. 2 mines (W. Va.). *See* Kay Moor, W. Va.
Kearns & Duggins mine (Utah), coal from, analysis of........................ 104
description of........................ 329
Kemmerer, Wyo., coal from near, analysis of 145
description of........................ 414
Kemmerer No. 1 mine (Wyo.), coal from, analysis of........................ 145
coal from, description of........... 413, 414
Kemmerer No. 4 mine (Wyo.). *See* Kemmerer, Wyo.
Keystone mine (Pa.), coal from, analysis of. 99
description of........................ 315
King mine, Colo., coal from, analysis of...... 24
description of...................... 164-165
Kirby, Wyo., coal from near, analysis of... 136, 137
description of...................... 395, 396
Kirksville, Mo., coal from near, analysis of. 41
description of........................ 207
Knight prospect (Utah), coal from, analysis of................................ 103
description of........................ 324
Knudsen mine (S. Dak.), coal from, analysis of................................ 100
description of........................ 318
Koehler, N. Mex., coal from near, analysis of. 58
description of........................ 237
Koehler No. 1 mine (N. Mex.). *See* Koehler, N. Mex.
Kooi, Wyo., coal from near, analysis of.... 141, 142
description of.................. 407, 408, 409
Kooi mine (Wyo.). *See* Kooi, Wyo.

L.

La Belle mine (Ohio), coal from, analysis of. 63
description of........................ 250
Lafayette, Colo., coal from near, analysis of.. 24
description of...................... 163, 164
Landreth No. 1 mine (Mo.), coal from, analysis of............................ 49
description of...................... 217, 218
Lane No. 1 mine (Mo.), coal from, analysis of. 46
description of........................ 214
Lansing, Kans., coal from near, analysis of.. 38, 39
description of........................ 202
Leavenworth, Kans., coal from near, analysis of............................ 39
description of...................... 202, 203
Leckie, W. Va., coal from near, analysis of. 116, 117
description of...................... 356-358
Leckie No. 1 and No. 2 mines (W. Va.). *See* Leckie, W. Va.
Leith, N. Dak., coal from near, analysis of.. 60
description of........................ 244
Lenore mine (Pa.), coal from, analysis of.... 95
description of........................ 307
Lenore No. 1 mine (Pa.), coal from, analysis of................................ 86
description of...................... 289, 290
Lenore No. 2 mine (Pa.), coal from, analysis of................................ 86
description of...................... 289, 290
Lewis, Mo., coal from near, analysis of...... 48
description of........................ 216
Lewis-Finley No. 1 mine (W. Va.), coal from, analysis of........................ 111
description of...................... 344, 345
Lexington bed, Mo., coal from, analysis of.............................. 45, 49, 51
description of............. 213, 218, 219, 220
sections of.............................. 219
Lincoln No. 1 mine (Pa.), coal from, analysis of............................ 78
description of........................ 276
Linmer mine (Pa.), coal from, analysis of.... 94
description of........................ 306
Littleton, Ala., coal from near, analysis of... 17
description of........................ 147

Page.

Little Vermilion mine (Ill.), coal from, analysis of..... 37
  description of..... 199
Litton, Tenn., coal from near, analysis of... 101
  description of..... 320, 321
Lodgepole, S. Dak., coal from near, analysis of 100
  description of..... 317
Logan No. 5 mine (Pa.), coal from, analysis of. 73
  description of..... 268, 269
Lord bed, Colo., coal from, anaylsis of..... 35
  description of..... 192
  section of..... 192
Lost Spring, Wyo., coal from near, analysis of..... 132, 133
  description of..... 388, 389, 390
Lou Creek mine, Colo., coal from, analysis of. 35
  description of..... 192
Louisville No. 1 mine (W. Va.), coal from, analysis of..... 123
  description of..... 370, 371
Louisville No. 2 mine (W. Va.), coal from, analysis of..... 123
  description of..... 370, 371
Louisville No. 3 mine (W. Va.), coal from, analysis of..... 123
  description of..... 370, 371
Lower Bolling bed, Ky., coal from, analysis of 39
  description of..... 203
  section of..... 203
Lower Bolling bed, Va., coal from, analysis of..... 107
  description of..... 335
  section of..... 335
Lower Elkhorn bed, Ky., coal from, analysis of..... 40
  description of..... 204, 205
Lower Freeport bed, Ohio, coal from, analysis of..... 61, 63
  description of..... 246, 247, 250
  sections of..... 246, 247, 250
Lower Freeport bed, Pa., coal from, analysis of..... 68, 69, 70, 71, 76, 77, 81, 89, 93, 95
  description of..... 259, 260, 261, 262, 263, 264, 265, 266, 273, 274, 275, 280, 281, 282, 294, 295, 302, 303, 306
  sections of..... 259, 262, 264, 265, 274, 281, 294, 302, 303, 306
Lower Hartshorne bed, Okla., coal from, analysis of..... 64
  description of..... 252, 253, 254
  sections of..... 254
Lower Kittanning bed, Pa., coal from, analysis of..... 69, 71, 72, 73, 74, 75, 76, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 95
  description of..... 263, 266, 267, 268, 269, 270, 271, 272, 273, 276, 277, 278, 279, 280, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 307
  sections of..... 263, 266, 267, 268, 269, 270, 271, 273, 276, 278, 279, 280, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 294, 295, 296, 297, 298, 299, 300, 307
Lower Rich Hill bed, Mo., coal from, analysis of..... 43, 44
  description of..... 210, 211

Page.

Lower Standiford bed, Ky., coal from, analysis of..... 39
  description of..... 203
Lucesco, Pa., coal from near, analysis of..... 99
  description of..... 315
Lucesco mine (Pa.). *See* Lucesco, Pa.
Lynwin mine (W. Va.), coal from, analysis of. 130
  description of..... 383, 384

M.

McAlester, Okla., coal from near, analysis of. 65, 66
  description of..... 254, 255
McAlester bed, Okla., coal from, analysis of.. 65, 66
  description of..... 253, 254, 255
McAlpin No. 1 mine (W. Va.), coal from analysis of..... 131
  description of..... 385, 386
McCallum mine (Colo.), coal from, analysis of 26
  description of..... 172
McCurtain, Okla., coal from near, analysis of. 64
  description of..... 251, 252
McCurtain bed, Okla. *See* McCurtain, Okla.
McDonald mine (Alaska), coal from, analysis of..... 21
  description of..... 155
McFarland prospect (Tenn.), coal from, analysis of..... 101
  description of..... 320, 321
McGuffey mine (Wyo.), coal from, analysis of. 138
  description of..... 400, 401
McHenry, Ky., coal from near, analysis of... 41
  description of..... 207
McHenry mine (Ky.). *See* McHenry, Ky.
McQuade station, W. Va., coal from near, analysis of..... 128
  description of..... 379, 380
Mackton mine (Mont.), coal from, analysis of. 54
  description of..... 224, 225
Madera, Pa., coal from near, analysis of..... 86, 87
  description of..... 290, 291, 292
Madison, Pa., coal from near, analysis of..... 99
  description of..... 315
Madrid, N. Mex., coal from near, analysis of. 59
  description of..... 240, 241, 242
Mancos, Colo., coal from near, analysis of.... 35
  description of..... 191, 192
Mancos bed, Utah, coal from, analysis of..... 105
  description of..... 331, 332
  section of..... 331, 332
Marceline, Mo., coal from near, analysis of... 49
  description of..... 217, 218
Marr mine (Colo.), coal from, analysis of..... 27
  description of..... 172
Martinsburg, Mo., coal from near, analysis of. 41
  description of..... 208
Mary Lee bed, Ala., coal from, analysis of.. 17
  description of..... 147
  sections of..... 147
Masontown, W. Va., coal from near, analysis of 127
  description of..... 377, 378
Masters bed, Wyo., coal from, analysis of.... 139
  description of..... 404, 405
  sections of..... 404
Matanuska River, Alaska, coal from near, analysis of..... 23
  description of..... 159, 160, 161, 162

Page.
Matoaka, W. Va., coal from near, analysis of. 123, 124
description of 371, 372
Maybeury, W. Va., coal from near, analysis of 119
description of 361
Mayfield No. 2 prospect (Wyo.), coal from, analysis of 137
description of 397
Medicine Lake, Mont., coal from near, analysis of 56
description of 232, 233
Meeker, Colo., coal from near, analysis of 35
description of 192, 193, 194
Meeker mine (Colo.). *See* Meeker, Colo.
Meeteetse, Wyo., coal from near, analysis of. 137, 138
description of 397, 401
Melbourne, Mo., coal from near, analysis of 45
description of 213
Mendota, Mo., coal from near, analysis of 49
description of 218
Mendota No. 2 mine (Mo.). *See* Mendota, Mo.
Mendota, Wash., coal from near, analysis of 108
description of 339, 340
Mendota No. 1 mine (Wash.). *See* Mendota, Wash.
Middle Kittanning bed, Pa., coal from, analysis of 75, 77, 87, 88
description of 272, 275, 292, 293
sections of 272, 293
Middle States mine (W. Va.), coal from, analysis of 115
description of 354, 355
Mill Creek, W. Va., coal from near, analysis of. 132
description of 386
Mill Creek mine (W. Va.), coal from, analysis of 112
description of 348, 349
Miller bed, Pa. *See* B or Lower Kittanning bed, Pa.
Miller No. 1 shaft (Pa.), coal from, analysis of. 79
description of 278, 279
Miller Run mine (Pa.), coal from, analysis of. 76
description of 273
Mindenmines, Mo., coal from near, analysis of 42
description of 208, 209
Misqualy Chief bed, Wash., coal from, analysis of 108
description of 341
section of 341
Missoula, Mont., coal from near, analysis of 55
description of 227, 228
Mitchell mine, Colo., coal from, analysis of 26
description of 171, 172
Mitchell mine (Wyo.), coal from, analysis of 134
description of 393
Monahan mine, Colo., coal from, analysis of. 26
description of 172
Monarch, Wyo., coal from near, analysis of 143
description of 409, 410
Monarch bed, Wyo., coal from, analysis of 141, 142, 143
description of 407, 408, 409, 410, 411
sections of 408, 409
Monarch mine (Wyo.). *See* Monarch, Wyo.
Mondak, Mont., coal from near, analysis of 57
description of 233

Page.
Monongah, W. Va., coal from near, analysis of 121
description of 365
Monongahela City, Pa., coal from near, analysis of 98, 99
description of 313, 314
Montana Station, W. Va., coal from near, analysis of 121
description of 365, 366
Montezuma bed, Wash., coal from, analysis of 108
description of 341, 342
section of 342
Montgomery mine (Colo.), coal from, analysis of 35
description of 193
Moorcroft, Wyo., coal from, near, analysis of 146
description of 416
Mora, W. Va., coal from near, analysis of 124, 125
description of 372, 373, 374, 375
Morgan Run mine (Pa.), coal from, analysis of 86, 87
description of 291, 292
Morgan Springs bed, Tenn., coal from, analysis of 101
description of 320, 321
Morley, Colo., coal from near, analysis of 29
description of 179, 180
Morley mine (Colo.). *See* Morley, Colo.
Morris, Ala., coal from near, analysis of 17
description of 148
Morrisdale, Pa., coal from near, analysis of 87, 88
description of 292, 293
Morrisdale No. 1, No. 2, and No. 3 mines. *See* Morrisdale, Pa.
Morrison, Colo., coal from near, analysis of 27
description of 173, 174
Morton, Wash., coal from near, analysis of 108
description of 340, 341
Mosby mine, Colo., coal from, analysis of 24
description of 165
Moshannon No. 10 mine (Pa.), coal from, analysis of 85
description of 287, 288
Moundville, Mo., coal from near, analysis of 51
description of 221
Moundsville, W. Va., coal from near, analysis of 122
description of 367, 368
Mount Ann, Alaska, coal from, analysis of 21
description of 154
Mount Hamilton, Alaska, coal from, analysis of 21
description of 155
Mowry mine (Colo.), coal from, analysis of 34
description of 189
Mulberry bed, Mo., coal from, analysis of 42, 43
description of 209, 210
Mulky bed, Mo., coal from, analysis of 41, 50, 51
description of 208, 220
Mullin mine (Ky.), coal from, analysis of 39
description of 203
Munson, Pa., coal from near, analysis of 88, 89
description of 293, 294

N.

Nanty Glo, Pa., coal from near, analysis of 78, 79
description of 276, 277
Neil No. 1 mine (Mo.), coal from, analysis of 46, 47
description of 214

Page.
Nelson bed, Tenn., coal from, analysis of...... 102
description of...... 322, 323
Nelson mine (S. Dak.), coal from, analysis of.. 100
description of...... 317
Nevada mine (Nev.), coal from, analysis of.... 57
description of...... 235
New Acme, Wyo., coal from near, analysis of. 143
description of...... 410, 411
New Acme mine (Wyo.). *See* New Acme, Wyo.
Newcastle, Colo., coal from near, analysis of 25
description of...... 168, 169
Newcomb mine (S. Dak.), coal from, analysis of...... 100
description of...... 317
New Home, Mo., coal from near, analysis of... 43
description of...... 210
New Home No. 1 mine (Mo.). *See* New Home, Mo.
New Prospect mine (Tenn.), coal from, analysis of...... 102
description of...... 322, 323
Nipper & Monroe mine (N. Dak.), coal from, analysis of...... 59
description of...... 242
Noble mine (Ohio), coal from, analysis of.... 63
description of...... 251
Norfolk mine (W. Va.), coal from, analysis of. 119
description of...... 361
Northern No. 2 mine (Mo.), coal from, analysis of...... 50
description of...... 219, 220
North Pole mine (Tenn.), coal from, analysis of...... 102
description of...... 322
North Side mine (Mont.), coal from, analysis of...... 53
description of...... 223, 224
No. 4 bed, Ind., coal from, analysis of........ 37
description of...... 199, 200
sections of...... 199
No. 5 bed, Ill., coal from, analysis of......... 37
description of...... 198, 199
sections of...... 198
No. 5 bed, Ind., coal from, analysis of........ 37
description of...... 200
section of...... 200
No. 6 bed, Ill., coal from, analysis of.......... 36, 37
description of...... 196-199
sections of...... 197, 198
No. 7 bed, Ohio, coal from, analysis of....... 63
description of...... 251
sections of...... 251
No. 8 bed, Ohio, coal from, analysis of....... 62, 63
description of...... 248, 249, 250
sections of...... 248, 249, 250
No. 9 bed, Ky., coal from, analysis of........ 40, 41
description of...... 205, 206, 207
Nyssa, Oreg., coal from near, analysis of..... 67
description of...... 257

O.

O'Brien claims (Alaska), coal from, analysis of...... 23
description of...... 159, 160, 161, 162
O'Gara No. 9 mine (Ill.), coal from, analysis of...... 37
description of...... 198, 199
Oak mine (Pa.), coal from, analysis of....... 68
description of...... 260
Oakdale mine (Colo.), coal from, analysis of.. 26
description of...... 170, 171
Oakley, Idaho, coal from near, analysis of.... 36
description of...... 195
Oak Station, Pa., coal from near, analysis of. 68
description of...... 260
Oakview, Colo., coal from near, analysis of... 26
description of...... 170, 171
Old Abe bed, N. Mex., coal from, analysis of.. 59
description of...... 239
section of...... 239
Old Abe mine (N. Mex.). *See* Old Abe bed, N. Mex.
Oneida mine (Pa.), coal from, analysis of.... 95
description of...... 307, 308
Onyon mine (Wyo.), coal from, analysis of.. 133
description of...... 389
Oregon No. 2 mine (W. Va.), coal from, analysis of...... 120
description of...... 363, 364
Oregon No. 3 mine (W. Va.), coal from, analysis of...... 120
description of...... 363, 364
Orris No. 1 mine (Mo.), coal from, analysis of.. 50, 51
description of...... 220
Osceola Mills, Pa., coal from near, analysis of...... 84, 85, 89
description of...... 286, 287, 288, 289, 294, 295

P.

Painted Rock, Mont., coal from near, analysis of...... 55
description of...... 228
Panama, Ill., coal from near, analysis of..... 37
description of...... 197, 198
Panama, Mo., coal from near, analysis of.... 51
description of...... 221
Panama mine (W. Va), coal from, analysis of. 122
description of...... 367, 368
Panama No. 1 mine (Ill.). *See* Panama, Ill.
Pardee, Va., coal from near, analysis of...... 107
description of...... 336
Pardee bed, Va. *See* Pardee, Va.
Pardee No. 1 mine (Va.). *See* Pardee, Va.
Parker Run mine (W. Va.), coal from, analysis of...... 121
description of...... 365, 366
Parks No. 1 mine (Mo.), coal from, analysis of. 46
description of...... 213
Parlett mine (Ohio), coal from, analysis of.... 62
description of...... 248, 249
Pawama No. 1 mine (W. Va.), coal from, analysis of...... 123
description of...... 371
Pawama No. 2 mine (W. Va.), coal from, analysis of...... 124
description of...... 372
Peacock prospect, N. Mex., coal from, analysis of...... 59
description of...... 241, 242

Page.

Peerless No. 1 mine (Pa.), coal from, analysis of.... 75
  description of.... 271,272
Penitentiary mine (Kans.), coal from, analysis of.... 38,39
  description of.... 202
Pennsylvania No. 2 mine (Pa.), coal from, analysis of.... 72,73
  description of.... 268
Pennsylvania No. 11 mine (Pa.), coal from, analysis of.... 76,77
  description of.... 273-275
Pennsylvania No. 12 mine (Pa.), coal from, analysis of.... 77
  description of.... 273-275
Pennsylvania No. 15 mine (Pa.), coal from, analysis of.... 71
  description of.... 266,267
Pennsylvania No. 21 mine (Pa.), coal from, analysis of.... 81
  description of.... 280-282
Pennsylvania No. 22 mine (Pa.), coal from, analysis of,.... 81
  description of.... 280-282
Penobscott mine (Pa.), coal from, analysis of. 97
  description of.... 311-312
Perins, Colo., coal from near, analysis of..... 27
  description of.... 175-176
Perins Peak mine (Colo.). *See* Perins, Colo.
Pharis No. 1 mine (Mo.), coal from, analysis of.... 47
  description of.... 214-215
Phillips mine (S. Dak.), coal from, analysis of 100
  description of.... 318
Philipsburg, Pa., coal from near, analysis of.. 89
  description of.... 295
Pierce mine (Mont.), coal from, analysis of.... 57
  description of.... 234
Pigg No. 1 mine (Mo.), coal from, analysis of. 48
  description of.... 216
Pikeview, Colo., coal from near, analysis of... 24
  description of.... 166
Pikeview mine (Colo.). *See* Pikeview, Colo.
Pikeville, Tenn., coal from near, analysis of... 101
  description of.... 320,321
Pinehill, Pa., coal from near, analysis of...... 96
  description of.... 309-310
Piney Fork, Ohio, coal from near, analysis of. 62,63
  description of.... 249
Piney Fork No. 1 and No. 2 mines (Ohio). *See* Piney Fork, Ohio.
Piney mine (W. Va.), coal from, analysis of. 114,115
  description of.... 352,353
Pinkham mine (N. Dak.), coal from, analysis of.... 59
  description of.... 242
Pinnacle mine (W. Va.), coal from, analysis of 125
  description of.... 373-374
Pittsburgh bed, Ohio, coal from, analysis of.. 62,63
  description of.... 248,249,250
  sections of.... 248,249,250
Pittsburgh bed, Pa., coal from, analysis of.... 67, 68,97,98,99,110,111,121
  description of.... 257,258,260,311, 312,313,314,315,344,345,365,366,367
Pittsburgh bed, Pa., section of.... 258, 260,311,312,313,314,345,364,366
Pittsburgh bed, W. Va., coal from, analysis of.... 122
  description of.... 367,368
  section of.... 367
Pittston, Pa., coal from near, analysis of..... 93
  description of.... 303
Pittston bed, Pa. *See* Pittston, Pa.
Plaza, N. Dak., coal from near, analysis of... 60
  description of.... 244
Plentywood, Mont., coal from near, analysis of 57
  description of.... 234
Plumb Run No. 1 mine (Ohio), coal from, analysis of.... 63
  description of.... 249-250
Plumb Run No. 4 mine (Ohio), coal from, analysis of.... 63
  description of.... 249-250
Plumb Run No. 5 mine (Ohio), coal from, analysis of.... 63
  description of.... 249-250
Plymouth No. 1 mine (Pa.), coal from, analysis of.... 80
  description of.... 279
Pocahontas No. 3 bed, W. Va., coal from, analysis of.... 114,115,116, 117,118,119,120,122,123,124,125,126
  description of.... 352, 353,354,355,356,357,358,359,361,364, 368,369,370,371,372,373,374,375,376
  section of.... 352,353,356,357,358,364, 368,369,370,371,372,373,374,375,376
Pocahontas No. 4 bed, W. Va., coal from, analysis of.... 115,120
  description of.... 353,354,355,363,364
  section of.... 353,354,363
Pocahontas No. 6 mine (W. Va.), coal from, analysis of.... 116
  description of.... 355-356
  section of.... 356
Pocahontas No. 6-B mine (W. Va.), coal from, analysis of.... 116
  description of.... 355-356
  section of.... 356
Pocahontas No. 7-A mine (W. Va.), coal from, analysis of.... 116
  description of.... 355-356
  section of.... 356
Portage, Pa., coal from near, analysis of.... 79,80,81
  description of.... 277-280
Potts Run No. 3. mine (Pa.), coal from, analysis of.... 85,86
  description of.... 289
Powell mine (N. Dak.), coal from, analysis of. 60
  description of.... 245
Powers mine (Va.), coal from, analysis of.... 105
  description of.... 332
Prather No. 1 mine (Mo.), coal from, analysis of.... 44,45
  description of.... 211-212
Price, Utah, coal from near, analysis of....... 103
  description of.... 324
Primero, Colo., coal from near, analysis of.... 29-32
  description of.... 180-182

Page.
Primero mines (Colo.). *See* Primero, Colo.
Proposia mine (Wyo.), coal from, analysis of. 134
    description of...................... 393-394
Puggsley mine (Wyo.), coal from, analysis of. 138
    description of...................... 399
Pullen No. 1 mine (Mo.), coal from, analysis of 42
    description of...................... 208,209
Purdon mine, Colo., coal from, analysis of.... 24
    description of...................... 166

R.

Raleigh, W. Va., coal from, analysis of....... 128
    description of...................... 380
Raleigh No. 1 and No. 3 mines (W. Va.). *See* Raleigh, W. Va.
Ralph, S. Dak., coal from near, analysis of.. 100
    description of...................... 317
Ralphton, Pa., coal from near, analysis of.... 96,97
    description of...................... 310,311
Ralphton No. 3 mine (Pa.) coal from, analysis of.............................. 96,97
    description of...................... 310
Ralphton No. 4 mine (Pa.), coal from, analysis of.............................. 97
    description of...................... 310,311
Ramah, Colo., coal from near, analysis of.... 24
    description of...................... 166
Raton bed, N. Mex., coal from, analysis of... 57,58
    description of...................... 235,236,237
    section of.......................... 236,237
Red Ash bed, Pa., coal from, analysis of...... 98
    description of...................... 304
Red Ash mine (Wyo.), coal from, analysis of. 138
    description of...................... 400
Red Bank mine (Mont.), coal from, analysis of 55
    description of...................... 230,231
Rees-Grass Creek mine (Utah), coal from, analysis of......................... 104
    description of...................... 329
Renick, Mo., coal from near, analysis of...... 50,51
    description of...................... 220
Reuben Bolling mine (Va.), coal from, analysis of......................... 107
    description of...................... 335
Reynolds mine (Utah), coal from, analysis of. 105
    description of...................... 331
Riach mine (Colo.), coal from, analysis of.... 26
    description of...................... 171
Rich Hill, Mo., coal from near, analysis of.... 44
    description of...................... 210,211
Rich Hill bed, Mo., coal from, analysis of.... 43,51
    description of...................... 221
Richard, W.Va., coal from near, analysis of. 126,127
    description of...................... 377
Richardson mine (Mont.), coal from, analysis of.............................. 55
    description of...................... 230
Richland bed, Tenn., coal from, analysis of... 102
    description of...................... 322
Richwood, W. Va., coal from near, analysis of. 114
    description of...................... 351,352
Ridgway, Colo., coal from near, analysis of.. 35
    description of...................... 192
Ritchie No. 1 pit (Mo.), coal from, analysis of. 44
    description of...................... 211
Ritchie No. 2 pit (Mo.), coal from, analysis of. 44
    description of...................... 211
Robertsdale, Pa., coal from near, analysis of.. 90
    description of...................... 297,298
Robertsdale mine (Pa.). *See* Robertsdale, Pa.
Rockvale, Colo., coal from near, analysis of.. 25
    description of...................... 167,168
Rockvale mine (Colo.). *See* Rockvale, Colo.
Roderfield, W. Va., coal from near, analysis of 117
    description of...................... 358,359
Rolfe, W. Va., coal from near, analysis of..... 118
    description of...................... 359,360
Rolfe mine (W. Va.). *See* Rolfe, W. Va.
Rosin mine (Wyo.), coal from, analysis of.... 133
    description of...................... 389,390
Roslyn, Wash., coal from near, analysis of.. 107,108
    description of...................... 338,339
Roslyn No. 1 and No. 2 mines (Wash.). *See* Roslyn, Wash.

S.

St. Mary's Creek, Alaska, coal from near, analysis of......................... 21
    description of...................... 155
Sagamore No. 1 mine (W. Va.), coal from, analysis of......................... 125
    description of...................... 374,375
Sagamore No. 2 mine (W. Va.), coal from, analysis of......................... 125
    description of...................... 374,375
Salina, Utah, coal from near, analysis of..... 104
    description of...................... 329
San Bois No. 2 mine (Okla.), coal from, analysis of......................... 64
    description of...................... 251,252
San Juan mine (Colo.), coal from, analysis of.. 27
    description of...................... 174
Schoenberger mine (Pa.), coal from, analysis of.............................. 97,98
    description of...................... 312
Scranton, N. Dak., coal from near, analysis of. 59
    description of...................... 243
Scranton mine (N. Dak.). *See* Scranton, N. Dak.
Sewanee bed, Tenn., coal from, analysis of.... 101
    description of...................... 319,320,321
Sewell bed, W. Va., coal from, analysis of..... 111, 112,113,114,132
    description of...................... 345, 346,347,348,349,350,351,352,386
    sections of......................... 345,346,348,350,352,386
Sewell mine (W. Va.), coal from, analysis of.. 111
    description of...................... 345,346
Sewickley bed, W. Va., coal from, analysis of. 121
    description of...................... 365,366
    sections of......................... 366
Shafer mine (Colo.), coal from, analysis of.... 33
    description of...................... 186
Sheldon No. 1 mine (Mo.), coal from, analysis of.............................. 47
    description of...................... 215
Sheridan No. 2 mine (Kans.), coal from, analysis of......................... 38
    description of...................... 201
Sholz mine (Mont.), coal from, analysis of... 55
    description of...................... 228